Camera Obscura

Developed as part of Complementary Learning: Arts-integrated Math and Science Curricula generously funded by the Martha Holden Jennings Foundation

Unit Overview - Camera Obscura

1. Power point (describing light) of CMA pieces, where is light coming from?
2. Power point (behavior of Light) Activity: come up with as many different light sources as possible (sun, light bulb, candle, lightening bug, glow stick)
3. Activity (build Camera Obscura)
    a. Rebuild the camera and refine image?
        i. Smaller hole with foil
        ii. Telescopic
        iii. Discuss results
4. Look at room size camera obscura for fun and as a lead into how artists may have used it for painting
5. Power point flat mirror and convex lens with Lens Activity to learn about the convex lens
6. Power point on artists who may have used camera obscura
7. Then art museum activity here are 3 paintings find them and from your observations which one of the 3 do you think was possibly made using camera obscura, why?
8. Assessments
    a. Completion of camera obscura
    b. Image formation with lens and lens activity
    c. CMA activity
    d. Quiz
    e. Student assessment questionnaire on lesson

Introduction

This is a Science and Art integrated lesson that can be used as an introduction to the behavior of light as it travels; it's interaction with a flat mirror and a convex lens as well as the inverse square law, law of reflection, thin lens equation and the magnification equation.

Grade Level and Subject Area

This lesson can be used in a 9^{th} grade Physical Science Class or a 12^{th} Grade Physics Class.

Prerequisite

This lesson assumes the student has already learned that light is an electromagnetic wave, and part of the electromagnetic spectrum (for freshmen). That velocity of light is a product of its frequency and wavelength and the structure of a wave (for both freshmen and seniors).

Materials

- The ability to show a power point presentation or access to a color copier to make copies of the images on the power points.
- Presentations and handouts
    - Guided Notes
    - Camera Obscura Vocabulary list
    - Powerpoint #1 – Describing Light Using Images from the CMA Collection
    - Powerpoint #2 – Behavior of Light
    - Powerpoint #3 – How to build a Camera Obscura + directions handout
    - Powerpoint #4 - Flat Mirror and Converging Lens
    - Powerpoint #5 – Scientists, Artists and the Camera Obscura
    - CMA Activities 1, 2 and 3 + directions
    - Camera Obscura Quiz
- For the hand held camera obscura you will need 2 oatmeal containers , tracing paper, rubber band, nail, sewing needle, tape, tin foil, scissors, razor knife (optional but makes cutting easier).
- For the optional activity of turning the classroom into a camera obscura you will need construction grade garbage bags and tape to cover your windows and doors and any other cracks that may leak light into the room and a piece of cardboard to use as an aperture.
- For the mirror and lens activity you will need a flat mirror, a convex lens, a tea light, note card and an "optical bench" as seen in the photo in the *image formation with a converging lens* activity instructions.

Key Concepts

Incandescent light	Image	Mirror
Fluorescent light	Real image	Converging lens
Chemo- luminescent light	Virtual image	Focal point
Light Emitting Diode	Object	2F point
Ray	Camera Obscura	Focal length
Luminous	Reflection	Refraction
Illuminated	Lens	Magnification

Lesson Plan

- **Begin with Power point 1** *Describing light Using Images from the CMA Collection*. The purpose of this power point is to lead a brief discussion on how light travels while observing how different artists have captured the motion of light in their paintings. By the end students should understand that light travels in straight lines, in all directions.

- **Power point 2**, *Behavior of Light* comes next. With this power point, again utilizing images from the CMA galleries we will identify how light is produced, the difference

between luminous and illuminated objects, the inverse square law, what the difference between an image and an object is. This will give us a vocabulary to use as a foundation for our first activity, building a camera obscura.

- **Power point 3** how to build a camera obscura, this power point was made into a word handout titled *Build a Camera Obscura Directions* which can be given to the students. As they build the camera, there is space for them to record their observations. The camera will be built two different ways utilizing 2 different independent variables. First we will attempt to get an image with a larger hole (nail) then we will attempt to refine that image by making the camera telescopic. Then we will remove the telescopic portion, reattach the original screen and make the hole smaller. Next we will reattach the telescopic portion and attempt to refine the image. The students should record all their findings and share them at the conclusion of the activity which will lead into power point 4.

- **Power point 4** *Flat Mirror and Converging Lens*. With this power point you will need the flat mirrors. We begin by looking at photographs from the CMA collection of camera obscura images and discussing why the image is always inverted. This returns us to our opening thoughts that light always travels in straight lines. Next we discuss ways we can manipulate the image using guiding questions to get the students to arrive at the idea of a mirror or a lens. At this point we can pass out the flat mirror, or if there is only one, hold it up for display. We continue with the power point looking at more photographs from the CMA collection that show reflections. The main idea here is to come to an understanding that flat mirrors always reflect true to form and identify the law of reflection. At this point we can differentiate between a virtual and real image. Once we have ascertained that mirrors reflect light and light is the image we can take the next step and enlarge or shrink the image with a lens. After a few new vocabulary terms and formulas we will stop at slide 36 and begin the lens activity.
  Image formation with a converging lens activity. This word document can be copied and used as a student guide for the activity. Upon completion of the activity the students should share their results. Through a class discussion we will identify the 4 of the 5 ways an image can be created using a convex lens. As well as what kind of image was formed (real or virtual) the location of the image vs. the location of the object and the magnification. Keep in mind, negative magnification means the image is smaller than the object! At this point we can return to power point 4 which will review our recent findings with some pictures as well. Power point 4 ends with an open ended question that leads into power point 5.

- **Power point 5** *Scientists, Artists and the Camera Obscura*. With this power point we will discuss a few early scientists that used mirrors and lenses and the time period in

which they did. This will lead into a discussion of artists that may have used optics in creating their art and our final activity.
Optional at this point after having seen some images of large camera obscuras we can ***t***urn the classroom into one using the construction grade garbage bags and cardboard.

- Our final activity begins by passing out a copy of *CMA ACTIVITY DIRECTIONS* along with one of the 3 *CMA AVTIVITY LISTS.* There are 3 lists so that not every student is doing the same work. This activity can be concluded with the student handing in their work, and presenting their conclusions to the class.

Assessment

There are a variety of assessments available here. First you can assess the students on construction of the camera obscura and the images they found. You can assess the students on the lens activity and the images they found and you can assess the students on their presentations from the CMA Activity at the end. These assessments are all subjective and depending on the grade level and abilities of the students can be weighted accordingly.

Extensions or the next step

From this point this lesson could be continued by investigating images formed from a divergent lens and from a concave mirror. You could build telescopes (reflecting or refracting).

Standards

Physics Standards (CMSD)

Describe how waves are affected by changes in media.

Apply advanced mathematical concepts in problem solving (e.g., geometry, trigonometry, and logarithms).

Ohio Department of Education Standards

By end of 9-10 program

Participate in and apply the processes of scientific investigation to create models and to design, conduct, evaluate and communicate the results of these investigations.

Construct, interpret and apply physical and conceptual models that represent or explain systems, objects, events or concepts.

Develop oral and written presentations using clear language, accurate data, appropriate graphs, tables, maps and available technology.

Comprehend that many scientific investigations require the contributions of women and men from different disciplines in and out of science. These people

study different topics, use different techniques and have different standards of evidence but share a common
purpose - to better understand a portion of our universe.

Investigate how the knowledge, skills and interests learned in science classes apply to the careers students plan to pursue

By end of the 11-12 program

Make appropriate choices when designing and participating in scientific investigations by using cognitive and manipulative skills when collecting data and formulating conclusions from the data.

Create and clarify the method, procedures, controls and variables in complex scientific investigations

Select a scientific model, concept or theory and explain how it has been revised over time based on new knowledge, perceptions or technology.

Describe the current and historical contributions of diverse peoples and cultures to science and technology and the scarcity and inaccessibility of information on some of these contributions.

Recognize that social issues and challenges can affect progress in science and technology. (e.g., Funding priorities for specific health problems serve as examples of ways that social issues influence science and technology.)

National Arts Standards

NA-VA.9-12.6 Making connections between visual arts and other disciplines

Achievement Standard:

Students compare the materials, technologies, media, and processes of the visual arts with those of other arts disciplines as they are used in creation and types of analysis

Students compare characteristics of visual arts within a particular historical period or style with ideas, issues, or themes in the humanities or sciences

This lesson was developed by Seamus Joyce, Architecture and Design at John Hay, 2007.

Guided Notes

Behavior of light Power point

Incandescent: _____

_____

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Fluorescent: _____

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_____

Chemo luminescent: _____

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_____

Light Emitting Diode:

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_____

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Ray:

_____

_____

_____

Luminous:

_____

_____

_____

Illuminated:

_____

_____

_____

Inverse Square law:

_____

Image: _____

_____

_____

Object: _____

_____

_____

Camera obscura: _____

Power point Flat Mirror and Converging lens

Reflection:

_____

_____

_____

Law of reflection: _____

_____

_____

Virtual image:

_____

_____

_____

Lens: _____

_____

_____

Principle axis: _____

_____

_____

Converging lens:
_____

Focal point:
_____

_____

_____

Focal length: _____

_____

_____

2f: _____

_____

_____

Refraction: _____

_____

_____

Thin lens equation: _____

_____

_____

Real image:
_____

_____

_____

Magnification: _____

_____

_____

Camera Obscura - Vocabulary

1. **Law of reflection** the reflected wave will reflect at the same angle as the incident wave strikes the surface.
2. **Inverse square law** the intensity of light on an object from a luminous source will decrease as the square of the distance between them increases.
3. **Incandescent** means white, glowing, or luminous with intense heat.
4. **Fluorescent** means producing light when electricity flows through a tube that is filled with a type of gas
5. **Chemo-luminescence** light produced by a chemical reaction
6. **Light emitting diode** two semiconductors close enough together for electrons to jump the gap between them and produce light.
7. A **ray** is a straight line representing the path of a narrow beam of light..
8. A **luminous body** emits light waves
9. An **illuminated body** reflects light waves
10. **Image** a visual representation of something,
11. **object** is a source of spreading, or diverging light rays
12. **camera obscura** or dark room
13. **Reflection**: The bouncing back of a particle or wave that strikes the boundary between two media.
14. **virtual image** because no light rays actually converge to form the image.
15. **Real image** an image formed by converging light rays.
16. **lens** is merely a carefully ground or molded piece of transparent material which refracts light rays in such as way as to form an image
17. **principle axis** the imaginary line running horizontally through a lens.
18. A **converging lens** is a lens which converges rays of light which are traveling parallel to its principal axis
19. **Focal point**
20. **2f** the position that is twice the distance of the focal point.
21. **Focal length** The distance from the vertical axis to the focal point
22. **Refraction**: The change in direction of a wave (bending) as it crosses the boundary between two media in which the wave travels at different speeds
23. **Magnification** is the ratio of the height of the object to the height of the image
24. **Thin lens equation** $1/f=1/do + 1/di$.

DESCRIBING THE MOTION OF LIGHT USING IMAGES FROM THE CMA COLLECTION

- In the following slides lets answer the following questions:
- Where is the light coming from?
- In which direction is it travelling?
- How do you know this?
- What evidence in the picture lends to this conclusion?

Light is shining down from the upper left corner and travelling in a **straight line** down to the right.

Christ and the Virgin in the House at Nazareth
Francisco de Zurbarán (Spanish, 1598-1664)

Where is the light coming from?
In which direction is it travelling?
How do you know this?
What evidence in the picture lends to this conclusion?

The light in coming down from the upper left direction of the oculus, in a **straight line.**

Where is the light coming from?

In which direction is it travelling?

How do you know this?

What evidence in the picture lends to this conclusion?

Interior of the Pantheon, Rome
Giovanni Paolo Panini (Italian, 1691-1765)

The light is coming in the window towards the photographer, in a **straight line.**

Odessa, U.S.S.R.
Elliott Erwitt (American, b. 1928)

Where is the light coming from?
In which direction is it travelling?
How do you know this?
What evidence in the picture lends to this conclusion?

The light travels down to the right from the upper left corner of the painting, in **straight lines.**

Expulsion of Adam and Eve
John Faed (Scottish, 1820-1902)

Where is the light coming from?

In which direction is it travelling?

How do you know this?

What evidence in the picture lends to this conclusion?

The light from the candle travels in all directions in a **straight line.**

A Funeral
Jean-Paul Laurens (French, 1838-1921)

Where is the light coming from?

In which direction is it travelling?

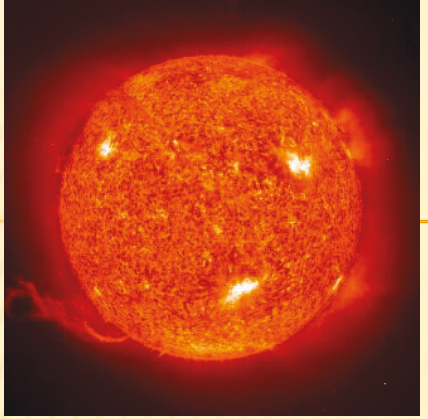
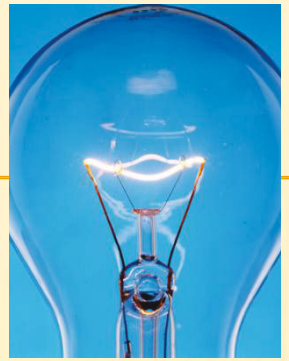
How do you know this?

What evidence in the picture lends to this conclusion?

- Is there one general rule we can state based upon what we observed on the previous slides?
- **Light travels in straight lines.**

BEHAVIOR OF LIGHT

How many sources of light can you identify?


Incandescent light

Incandescent means white, glowing, or luminous with intense heat.

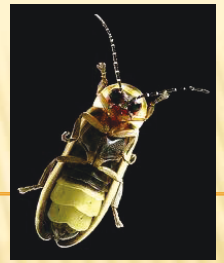
Light from heat like the sun or a filament in an incandescent bulb.

It is not necessary for things to be burning to emit light. If a piece of metal is heated to a high temperature it gets **red hot** (600°C upwards) or maybe **white hot** (above 3000°C) as in the case of an incandescent light. (the glass bulb keeps air away from the hot metal filament and so it does not burn.)

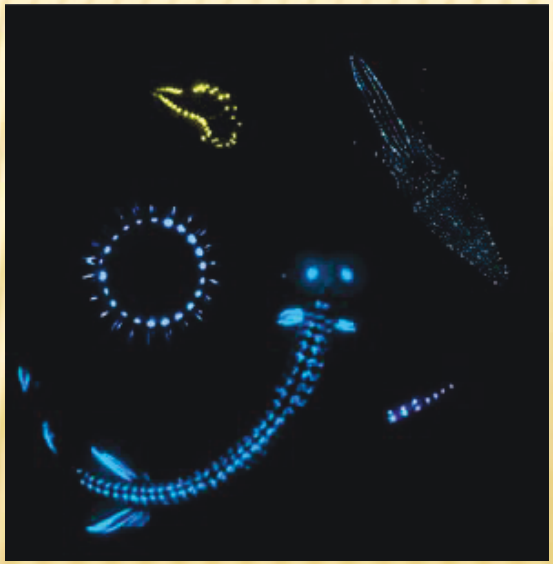
FLUORESCENT MATERIALS

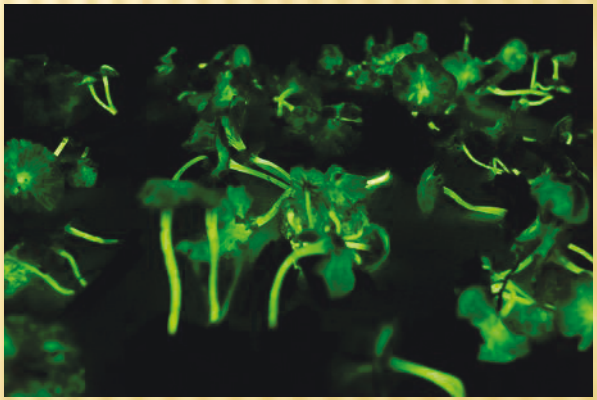
- **Fluorescent** means producing light when electricity flows through a tube that is filled with a type of gas
- In these the light is emitted by a white powder on the inside of the glass; the powder does not have to be hot but it must be irradiated by ultra violet light.

CHEMO-LUMINESCENCE



- **chemical** reactions **produce light** (without noticeable heat) and a number of living things make use of this technique, e.g. fireflies, some fungi, many deep-sea fish and other marine animals. So-called ‘glow sticks’ operate in the same way.



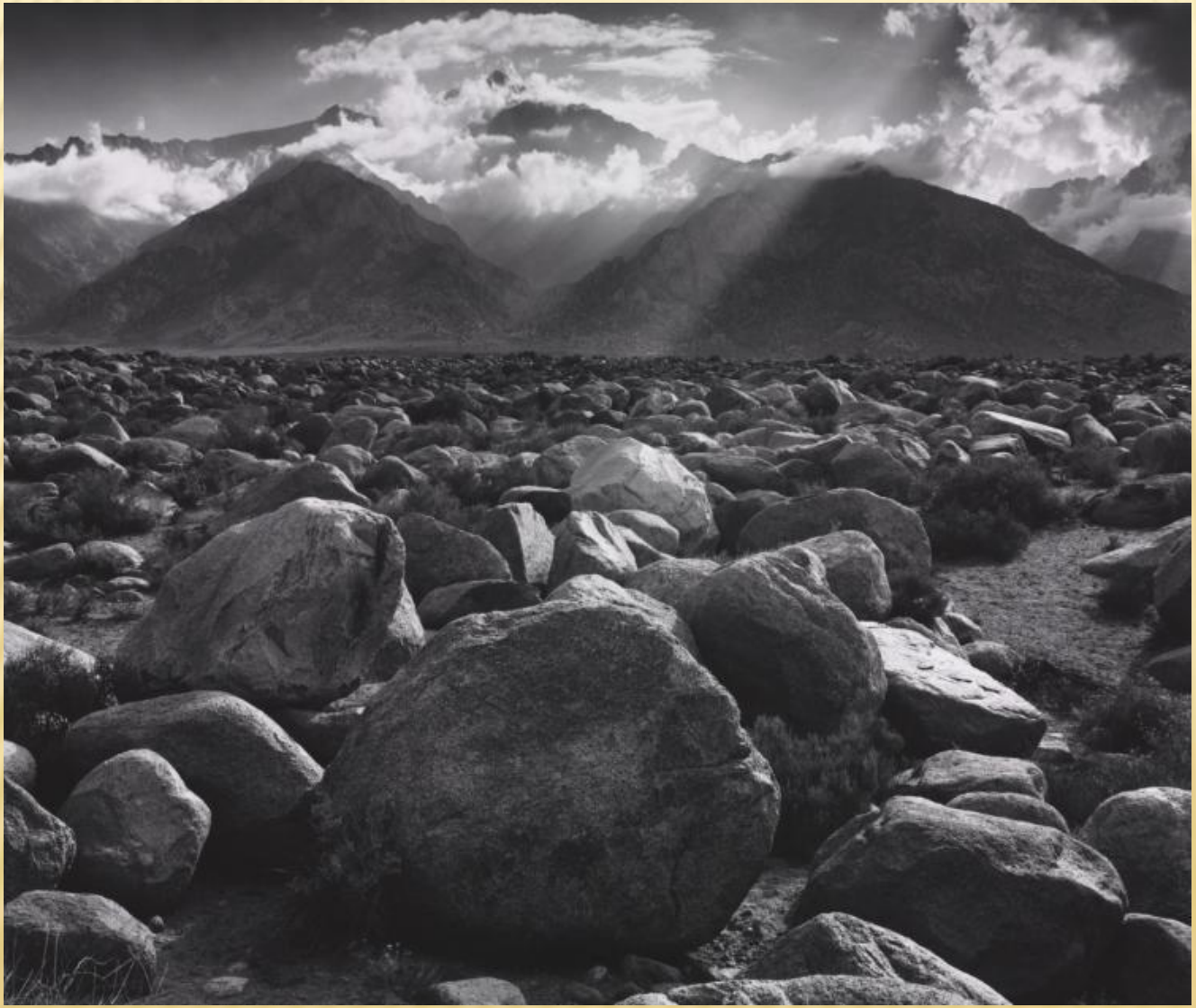


LEDS (LIGHT EMITTING DIODES)

They are illuminated solely by the movement of electrons in a semiconductor material, basically LEDs utilize two semiconductors in close proximity. As electrons jump the gap between the two semiconductors they lose energy and emit photons.

- No matter how the light is produced, the wave will still travel in a **straight line**.
- A **ray** is a straight line representing the path of a narrow beam of light.
- Any beam of light can be thought of as being made from many rays.

Mount Williamson, The Sierra Nevada, from Manzanar, California
Ansel Adams (American, 1902-1984)



Notice how Ansel Adams captured the rays of light shining down from the upper right area of the photograph. Also notice that those rays of light are traveling in straight lines.

QUESTION?

What is the difference between **Luminous** and **Illuminated**?

Let us take a look at the following photographs from the CMA collection and see if we can create a definition for **luminous** and **illuminated** by identifying the **luminous** and **illuminated** portions in each photograph.

Untitled (Man and Mirror)

Carrie Mae Weems (American, b. 1953)

Two Acrobats, Cirque Medrano

Brassaï (French, 1899-1984)

Ohio City

Douglas Lucak (American, b. 1959)

- A **luminous** body emits light waves
- An **illuminated** body reflects light waves produced by a **luminous** body .

QUESTION?

What happens to an illuminated object as it moves away from a luminous object and why?

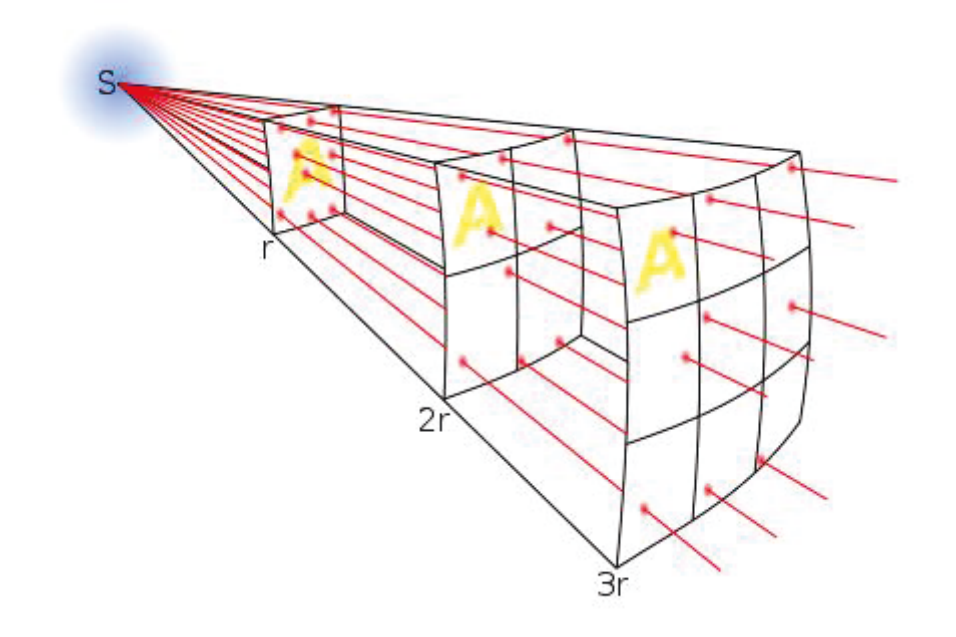
INVERSE SQUARE LAW

In this case, for light, we can say that the intensity of light on an object from a luminous source will decrease as the square of the distance between them increases.

When r=1 the intensity at r is full strength

At 2r intensity will be ¼ strength

At 3r intensity will be 1/9 strength



QUESTION?

- How are you able to see this power point ?

- That's right, the screen is reflecting the light from the projector creating an **Image.**
- An **Image** can be defined as:
- *a* **:** the optical counterpart of an object produced by an optical device (as a lens or mirror) or an electronic device
- *b* **:** a visual representation of something: as *(1)* **:** a likeness of an object produced on a photographic material *(2)* **:** a picture produced on an electronic display (as a television or computer screen)

- In order to have an image, we have to have an object first.
- An **object** is a source of spreading, or diverging light rays. An object may be luminous (candle or lamp) but more often an object is illuminated (you, book, moon). Illuminated objects reflect diffusely in all directions.

Activity

One of the earliest tools used to create an image is the ***Camera Obscura*** which translates to "dark room."

We are going to build a hand held camera obscura and use it to analyze the behavior of light, and analyze the image formed.

Then we will discuss how we could improve upon the image, and attempt to improve it.

Next we will investigate how the camera obscura may have been used by various scientists and artists throughout history.

Activity

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MATERIALS

- 2 Quaker oat cans
- Tape
- Scissors
- Razor knife
- Nail
- Pin
- Foil
- Tracing paper
- Rubber band

- First remove the lid from one of your containers

- Next put a piece of tracing paper over the top of the container and cut it in a circle just larger than the container.

- Place the rubber band around the paper to hold it firmly against the canister.

- Next use the nail to make a hole in the bottom of the container as close to the middle as you can.

- At this point lets try and get an image and discuss what we see, in the space to the right you can sketch your image and jot down some notes about it.

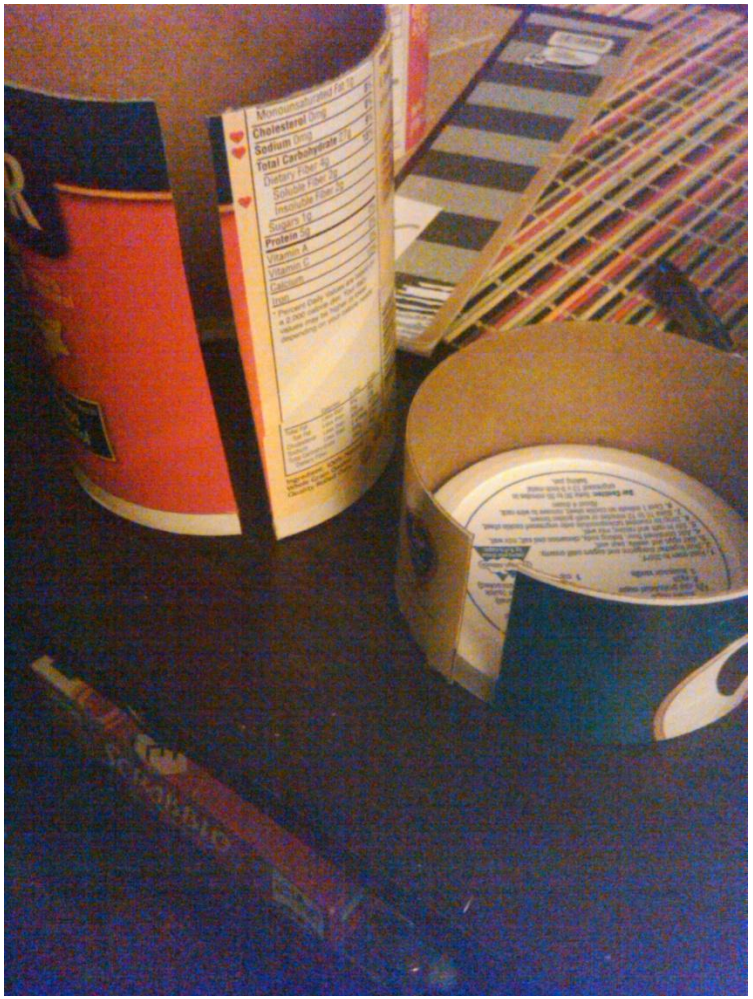
- What can we do to improve the image?
- Can we make it clearer (sharper)?
- How?

Lets make it telescopic

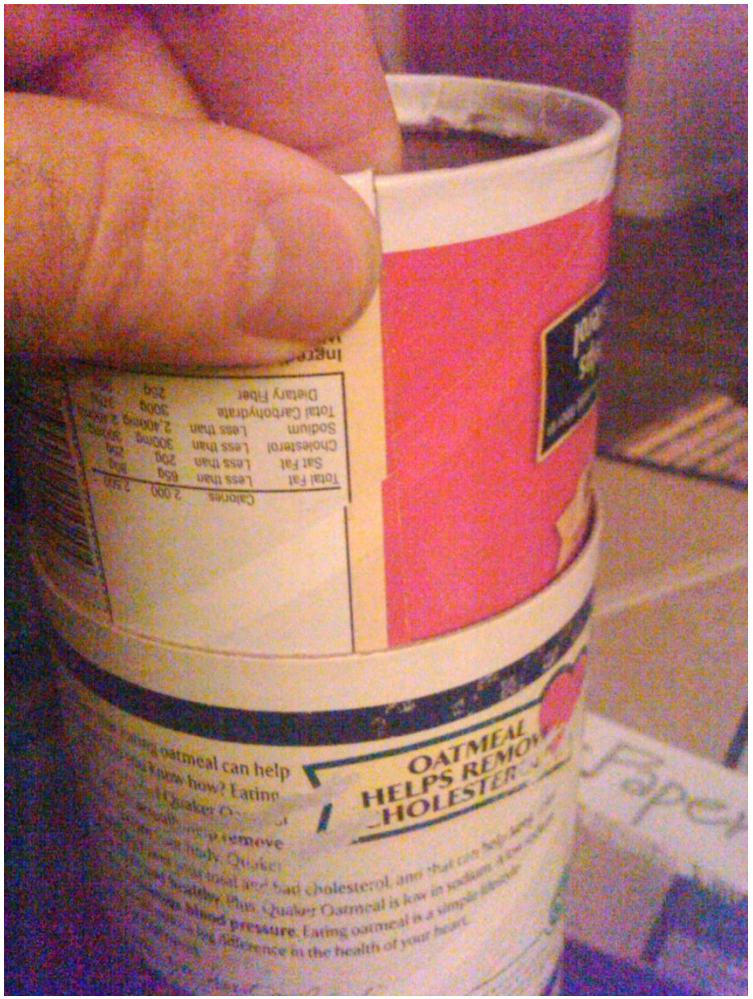
- First take your second oatmeal container and cut the bottom out of it.

- Then cut the container so you have two tubes, one about 1/3 the size of the other.

- Next, slice those containers lengthwise.



- Now, wrap the longer container in on itself and insert it into your original container so that it just fits but is able to slide freely. Then tape the second container together so it maintains this new shape.

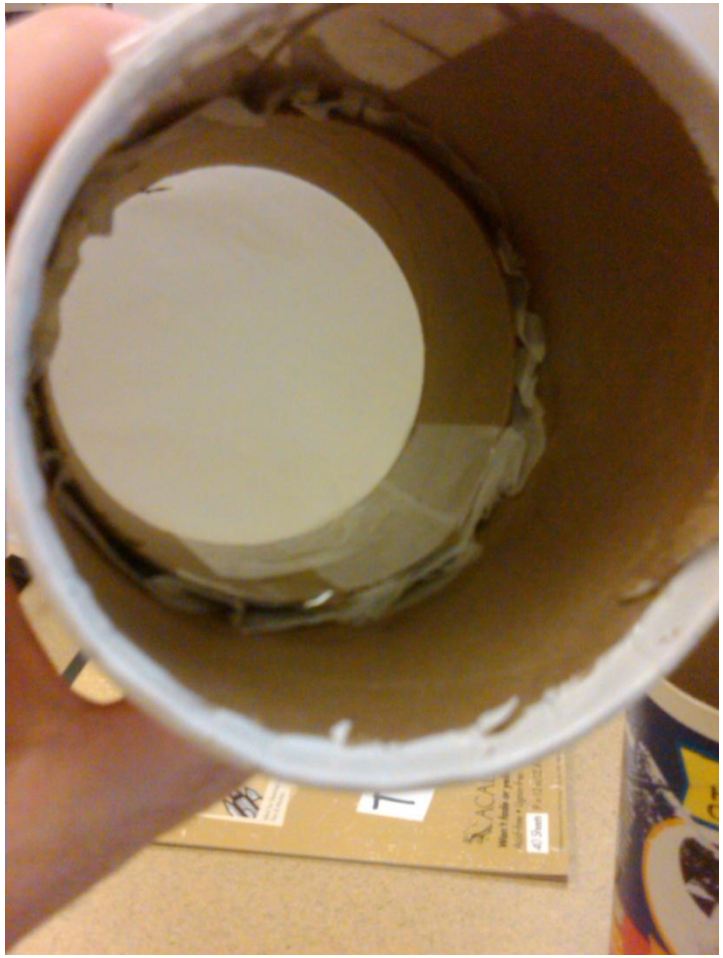


- Repeat this procedure with the smaller container.

- So now we have 3 pieces. The main camera, the long tube that fits just inside the main camera and the small tube that fits just inside the long tube.

- Now wrap a piece of tracing paper around the small tube

- Insert small tube into long tube, trim the paper and push the small tube all the way through to the end.



- Insert the long tube SLOWLY into the main camera so the tracing paper is closest to the hole

- Now see what sort of image is formed. What happens when you move the tube in and out of the main camera? Make a sketch and jot down some notes about your image here.

- Now lets go back to the single camera and adjust the hole. SAVE ALL THE TELESCOPIC PARTS WE WILL REUSE THEM!

- CAREFULLY make a larger hole as close to the middle as you can.

- Tape the edges of the tin foil down so the foil covers the hole and is as flat and tight as possible.

- Use the smallest sewing needle to poke a hole in the tin foil.

- Now put the original piece of tracing paper on with the rubber band and see what kind of image you get.

- Sketch your image and write down any notes about it in the space to the right.

- Now remove the tracing paper and insert your telescopic piece.

- Find an image, sketch it and write down any notes you have in the space to the right.

The next step?

Can we make a larger camera obscura? If so, how?

Slide 1

Activity

One of the earliest tools used to create an image is the ***Camera Obscura*** which translates to “dark room.”

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Then we will discuss how we could improve upon the image, and attempt to improve it.

Next we will investigate how the camera obscura may have been used by various scientists and artists throughout history.

Slide 2

MATERIALS

- 2 Quaker oat cans
- Tape
- Scissors
- Razor knife
- Nail
- Pin
- Foil
- Tracing paper
- Rubber band

Slide 3

- First remove the lid from one of your containers

Slide 4

- Next put a piece of tracing paper over the top of the container and cut it in a circle just larger than the container.

Slide 5

- Place the rubber band around the paper to hold it firmly against the canister.

Slide 6

- Next use the nail to make a hole in the bottom of the container as close to the middle as you can.

Slide 7

- At this point lets try and get an image and discuss what we see, in the space to the right you can sketch your image and jot down some notes about it.

Slide 8

- What can we do to improve the image?
- Can we make it clearer (sharper)?
- How?

Slide 9

Lets make it telescopic

- First take your second oatmeal container and cut the bottom out of it.

Slide 10

- Then cut the container so you have two tubes, one about 1/3 the size of the other.

Slide 11

- Next, slice those containers lengthwise.

Slide 12

- Now, wrap the longer container in on itself and insert it into your original container so that it just fits but is able to slide freely. Then tape the second container together so it maintains this new shape.

Slide 13

- Repeat this procedure with the smaller container.

Slide 14

- So now we have 3 pieces. The main camera, the long tube that fits just inside the main camera and the small tube that fits just inside the long tube.

Slide 15

- Now wrap a piece of tracing paper around the small tube

Slide 16

- Insert small tube into long tube, trim the paper and push the small tube all the way through to the end.

Slide 17

- Insert the long tube SLOWLY into the main camera so the tracing paper is closest to the hole

Slide 18

- Now see what sort of image is formed. What happens when you move the tube in and out of the main camera? Make a sketch and jot down some notes about your image here.

Slide 19

- Now lets go back to the single camera and adjust the hole. SAVE ALL THE TELESCOPIC PARTS WE WILL REUSE THEM!

Slide 20

- CAREFULLY make a larger hole as close to the middle as you can.

Slide 21

- Tape the edges of the tin foil down so the foil covers the hole and is as flat and tight as possible.

Slide 22

- Use the smallest sewing needle to poke a hole in the tin foil.

Slide 23

- Now put the original piece of tracing paper on with the rubber band and see what kind of image you get.

Slide 24

- Sketch your image and write down any notes about it in the space to the right.

Slide 25

- Now remove the tracing paper and insert your telescopic piece.

Slide 26

- Find an image, sketch it and write down any notes you have in the space to the right.

Slide 27

The next step?

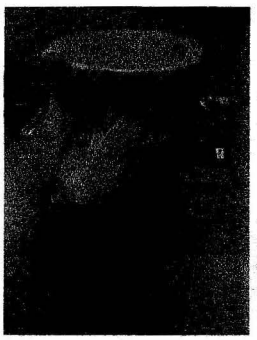
Can we make a larger camera obscura? If so, how?

Slide 22

- Use the smallest sewing needle to poke a hole in the tin foil.

Slide 23

- Now put the original piece of tracing paper on with the rubber band and see what kind of image you get.



Slide 24

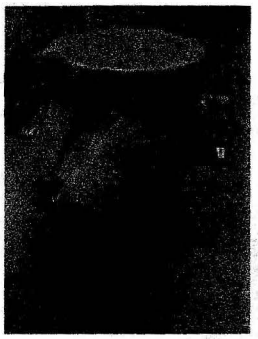
- Sketch your image and write down any notes about it in the space to the right.

Slide 22

- Use the smallest sewing needle to poke a hole in the tin foil.

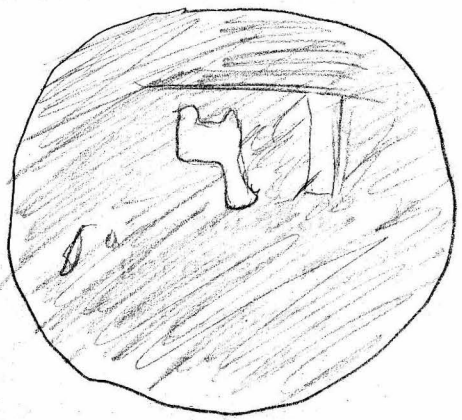
Slide 23

- Now put the original piece of tracing paper on with the rubber band and see what kind of image you get.



Slide 24

- Sketch your image and write down any notes about it in the space to the right.



- much more clear of a picture.
- Mona appeared upside down and backwards.

Slide 22

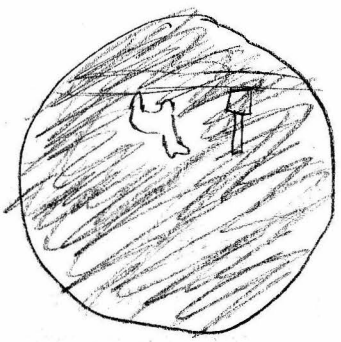
- Use the smallest sewing needle to poke a hole in the tin foil.

Slide 23

- Now put the original piece of tracing paper on with the rubber band and see what kind of image you get.

Slide 24

- Sketch your image and write down any notes about it in the space to the right.



-image is upside down + reflected
-still slightly fuzzy + small
-best image so far (in quality)
-Now can see brush next to it.

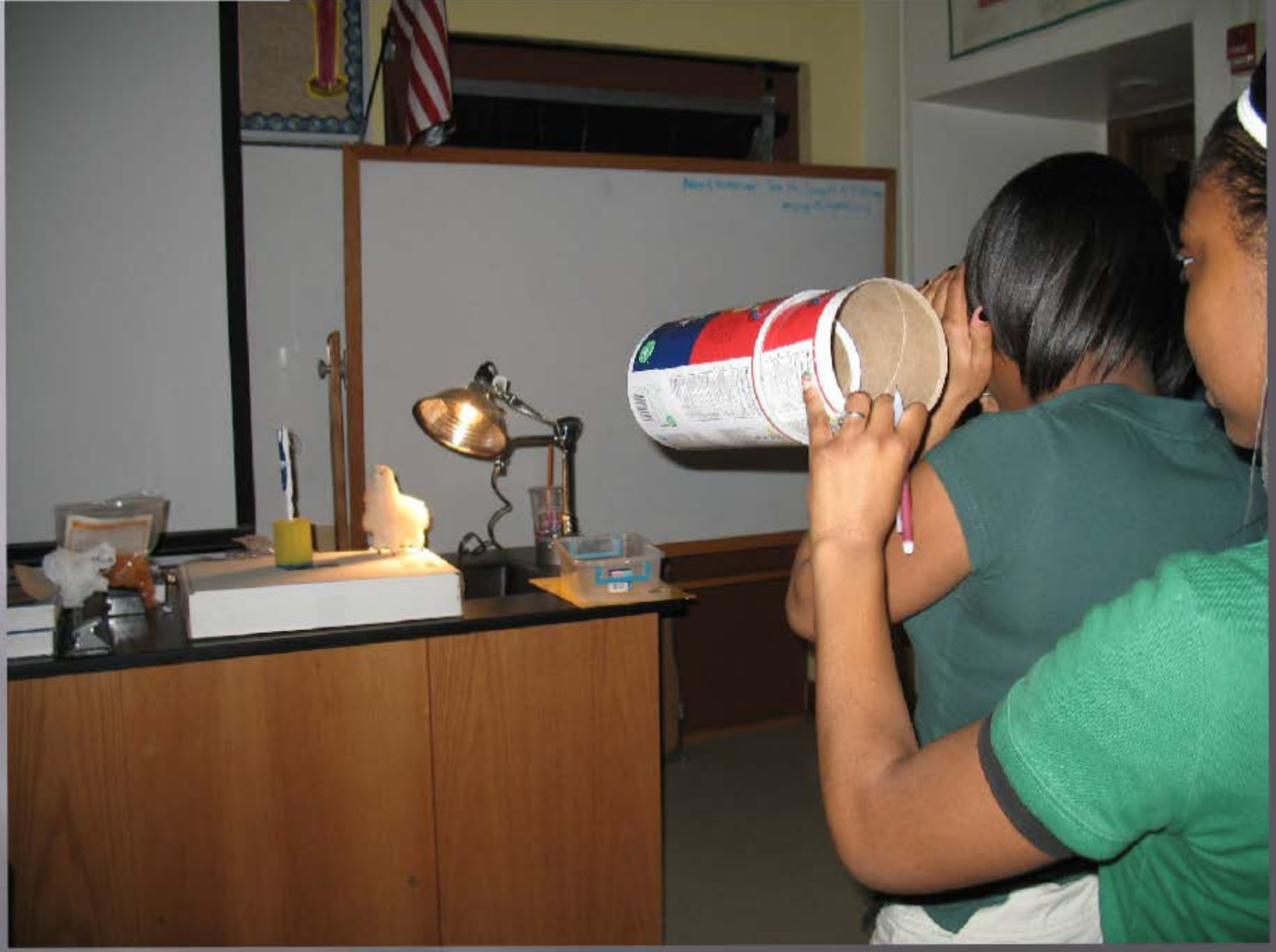
CAMERA OBSCURA DAY 1

Building the camera and using the distance between the hole and the screen as an independent variable.

Building the hand held camera obscura

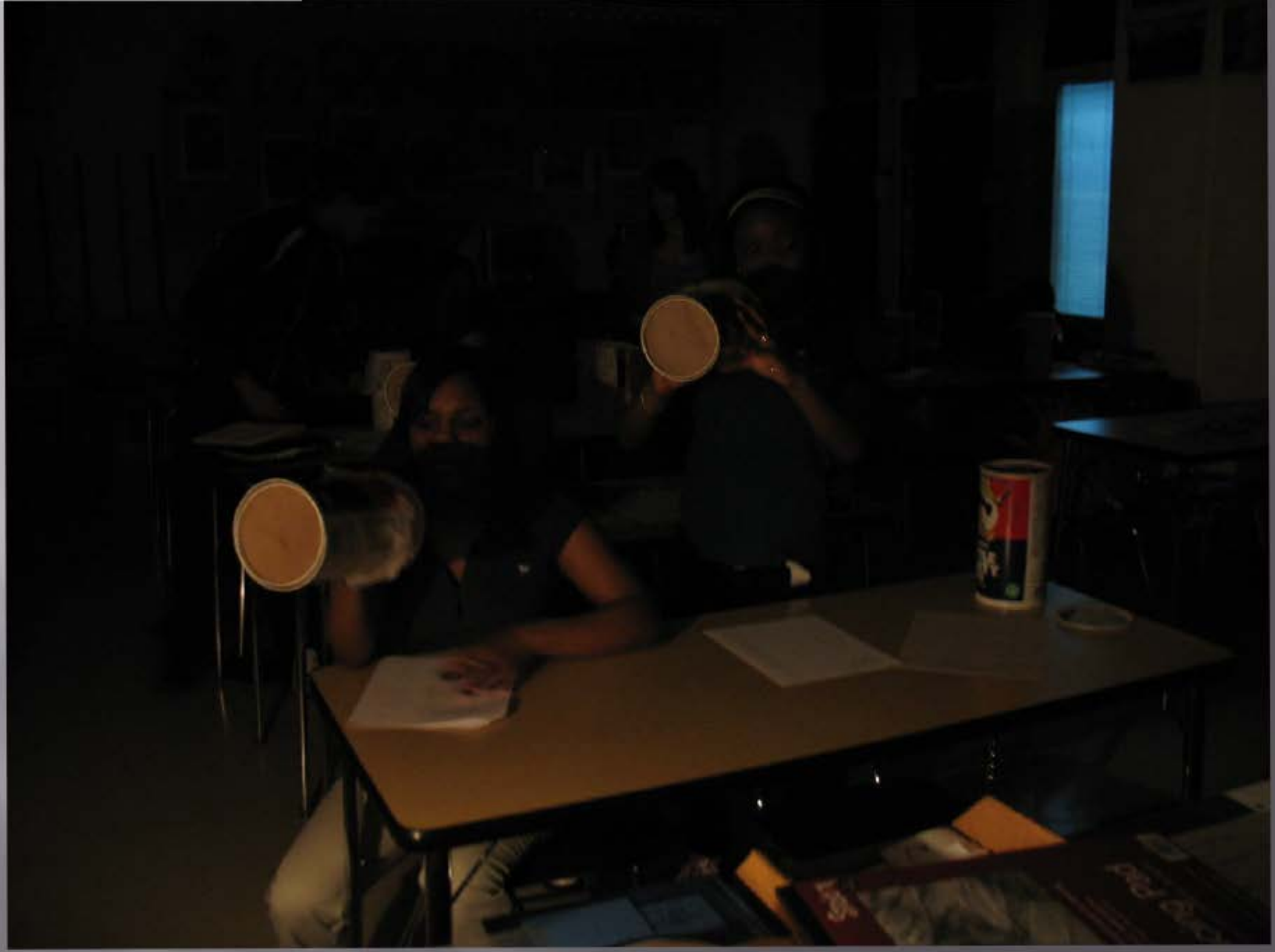
Building the hand held camera obscura

Building the hand held camera obscura



First attempt at finding an image

Finding an image

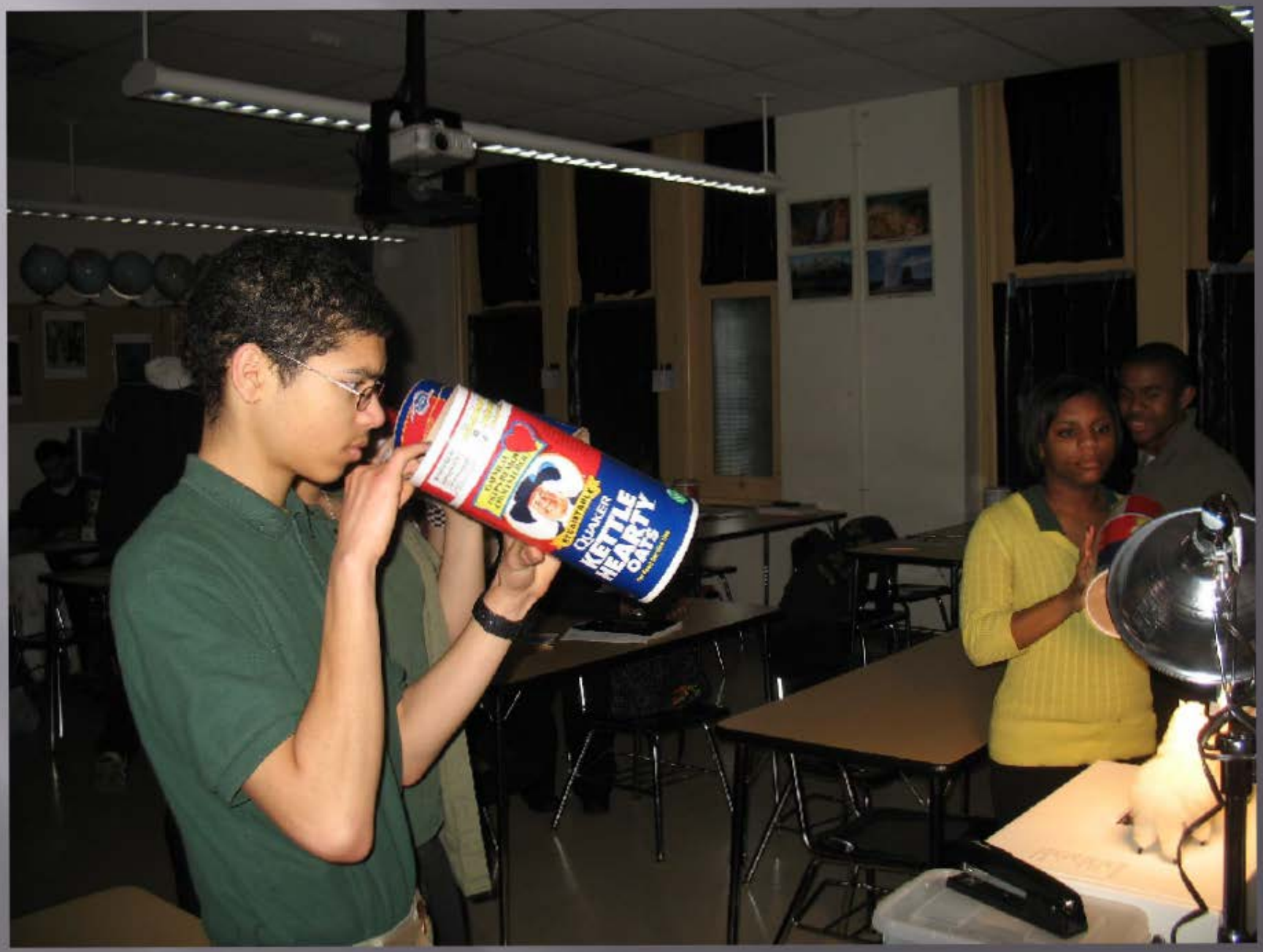


Finding an image with a large hole

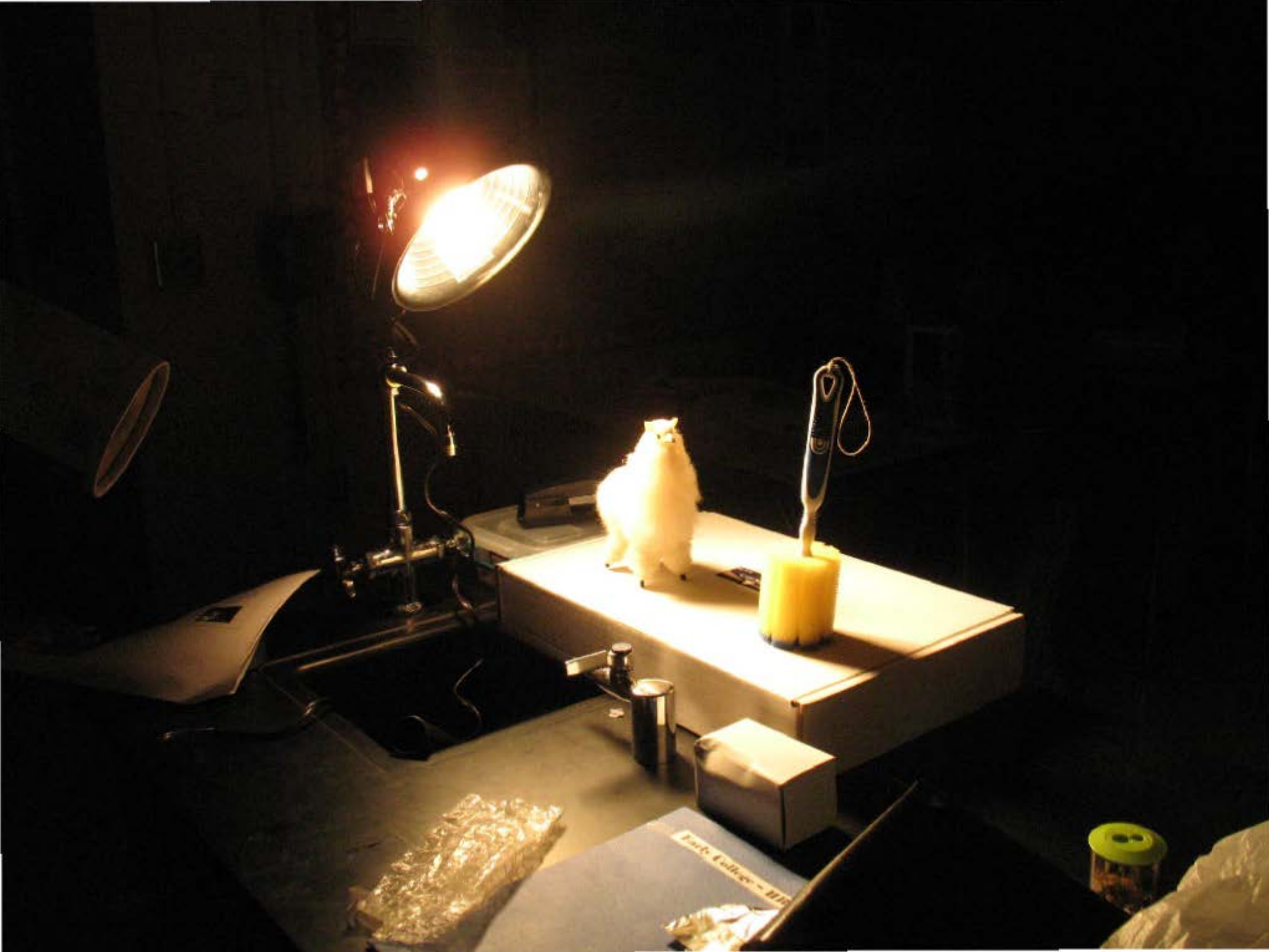
DAY 2

Using the hole as an independent variable

We've enlarged the hole and covered it with tin foil, so we can slowly increase the size with different size pins to find the best image.


QUAKER
KETTLE
HEARTY
OATS

Our objects are a stuffed Llama and a dish brush under a 60Watt incandescent bulb



I see it!!!!

Very small pin hole on this camera obscura

An inverted Llama!!

TURNING THE CLASSROOM INTO A CAMERA OBSCURA

Covering the windows and doors and cutting the hole

With the lights off

The view outside the window


CLEVELAND SCHOOL OF THE

Image formation on a sheet

Image formation without the sheet.

The Image

- When building your hand held camera obscura what effect did the size of the hole have?

- What effect did moving the image locater (tracing paper) have?

- Lets take a look at the following photographs from the CMA, taken of images made by a camera obscura.
- What do you notice about these images?
- How do they compare to the image you found on your hand held camera obscura?

Camera Obscura Image of Houses across the Street in Our Bedroom

Abelardo Morell (American, b. 1948)

Camera Obscura Image of Canal Park, Akron, Ohio

Abelardo Morell (American, b. 1948)

- Why is the image always upside down?

- Remember light travels in straight lines, so the light from the top of the object will travel to form an image at the bottom of the screen and the bottom to the top.

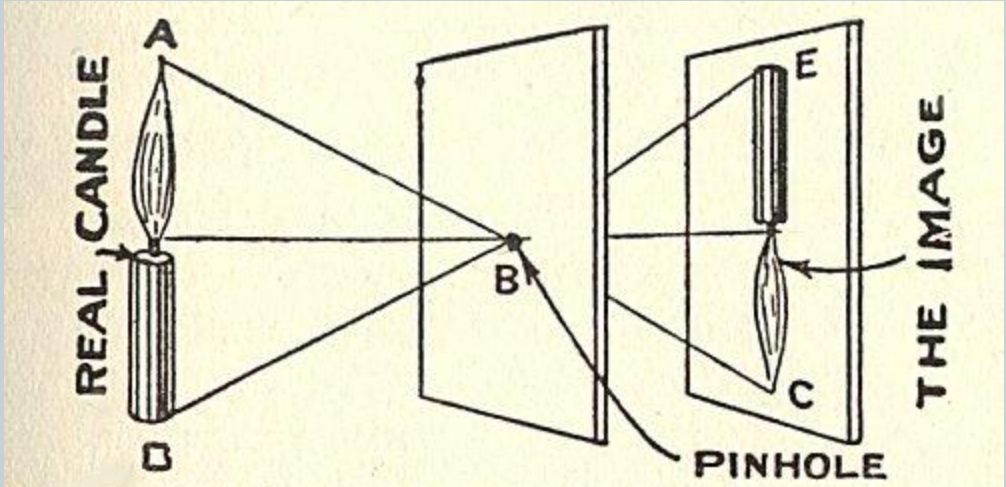


FIG. 131.—How Light and a Pinhole Form an Image.

The pinhole camera and camera obscura principle illustrated in 1925, in *The Boy Scientist*.

- So can we manipulate this image to make it an upright image?
- How?
- We could use mirrors or lenses.

- First we'll discuss the flat mirror.
- What do mirrors do?
- They reflect light.

- **Reflection**: The bouncing back of a particle or wave that strikes the boundary between two media.

- Looking at the following photographs of reflections in flat mirrors, from the CMA collection, what observations can you make *about the reflections*?

Reflection in Mirror

Ernst Schieron (German)

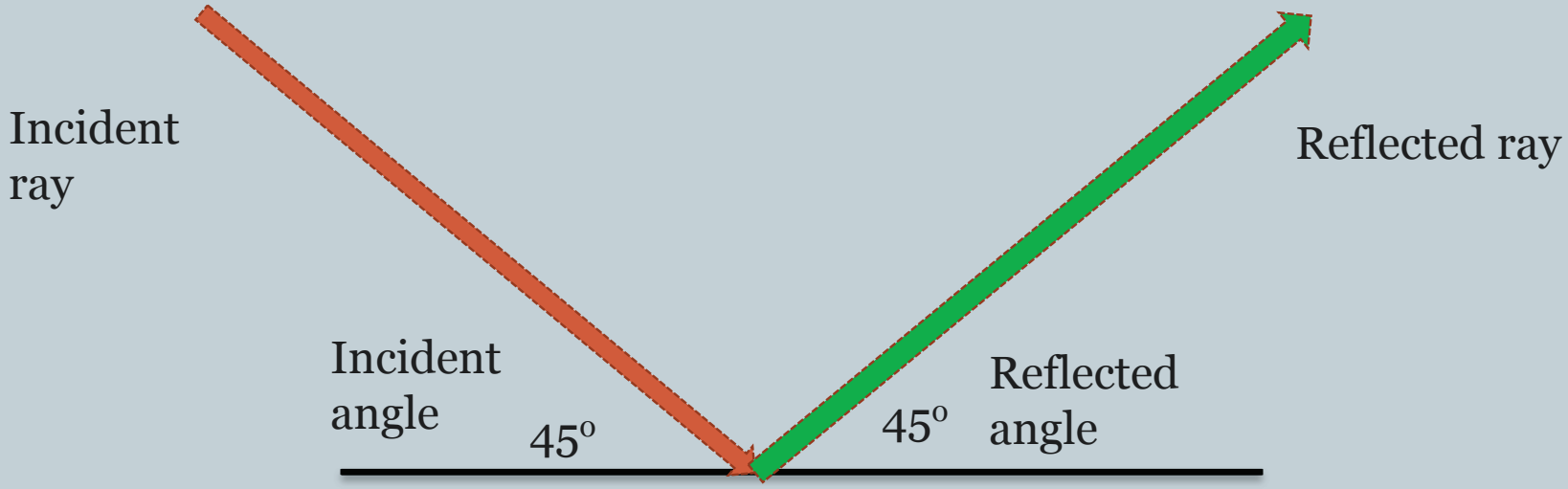
Eckstein with Lipstick

Lovers in a Bistro, Rue Saint-Denis
Brassaï (French, 1899 - 1984)

- What did you notice about the image (reflection) in relation to the object (thing being reflected)?
- The reflections are the same size as the object being reflected.
- Keeping in mind that light travels in straight lines can we explain this phenomena?

The Law of Reflection

- The angle of incidence equals the angle of reflection.



- Because of this, reflections from a plane mirror are the same size shape and orientation as the image.
- When you look into a flat mirror the number of light rays being reflected is infinite.
- Every single reflected ray obeys the law of reflection.
- The image is located the same distance inside the mirror as the object is away from the mirror.

- When looking at a flat mirror Like the mirror in the bathroom) a virtual image is formed.
- The image is called a **virtual image** because no light rays actually converge to form the image.
- The image is located inside the mirror!
- The image is the same distance inside the mirror as the object is away from the mirror.

- Lets look at Eckstein with Lipstick again (on the next slide) notice the distance between the object and the mirror and the image and the surface of the mirror.

- Also notice that every ray of light is reflected off the mirror, no light passes through the mirror, however the image appears to be inside the mirror, this is why we call it virtual.

Eckstein with Lipstick

- Mirrors are essentially glass mounted on a shiny metal surface.

- A sheet of glass without a metal surface behind it can also act as a flat mirror as seen in the following picture from the CMA collection.

Untitled (Window Reflection, 5th Avenue)

Lisette Model (American, 1901-1983)

- Flat mirrors can be used to reflect light onto a surface too.

- Just look at a disco ball!

- Ok, so we know we can reflect the image (light) onto another surface, but is there any way we can refine the image?
- Can we enlarge or shrink the image?
- Can we invert the image?
- **YES!!!**

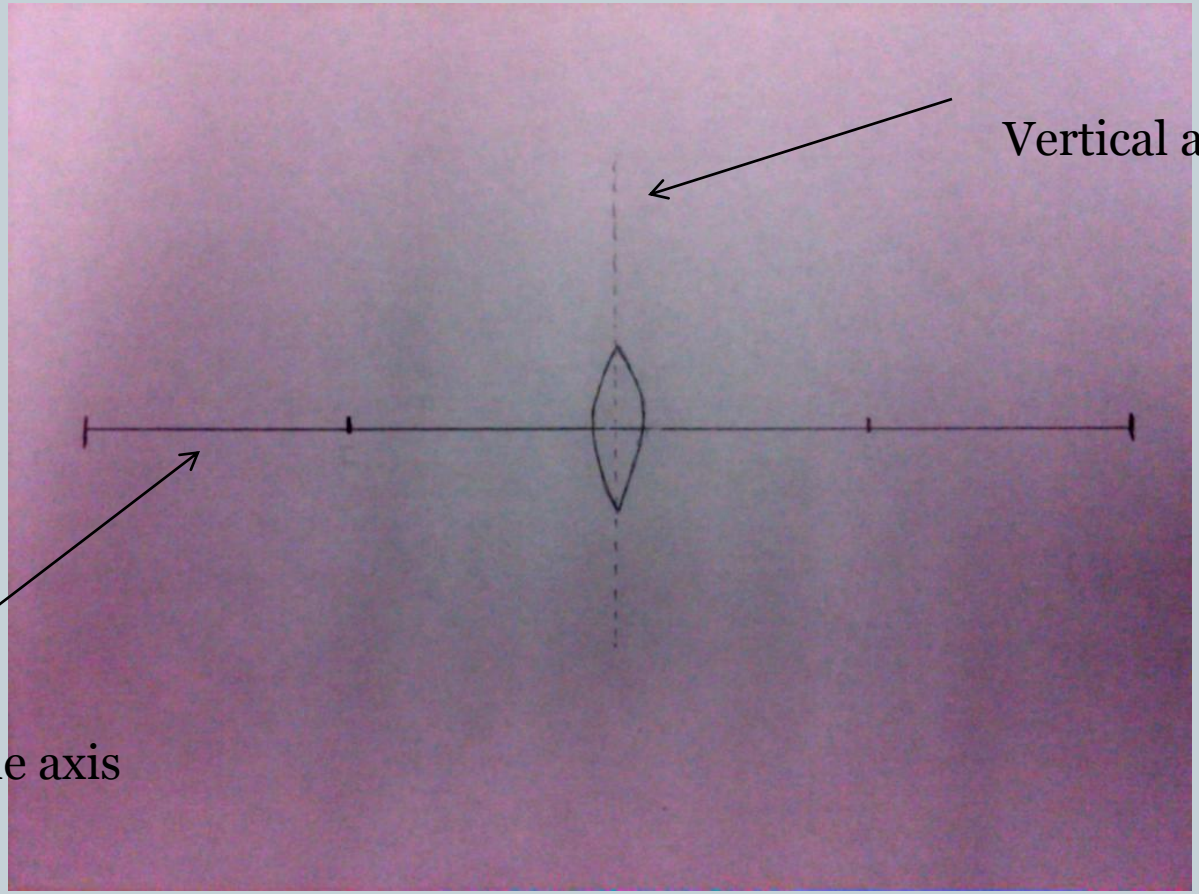
The Converging Lens

- A **lens** is merely a carefully ground or molded piece of transparent material which refracts light rays in such as way as to form an image.

- Our focus will be upon a converging lens that is symmetrical across its horizontal axis - known as the **principal axis**.

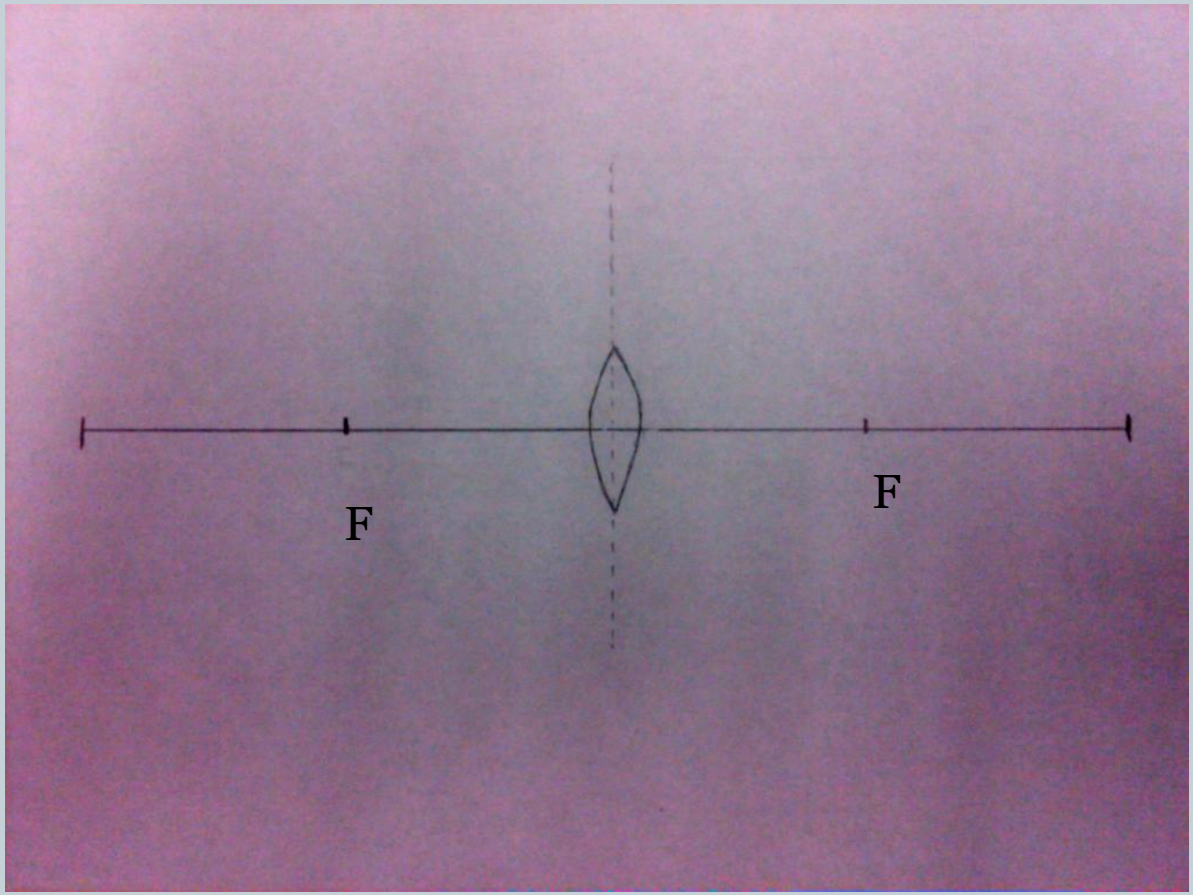
- A **converging lens** is a lens which converges rays of light which are traveling parallel to its principal axis.

- Converging lenses can be identified by their shape; they are thicker across their middle and thinner at their upper and lower edges.

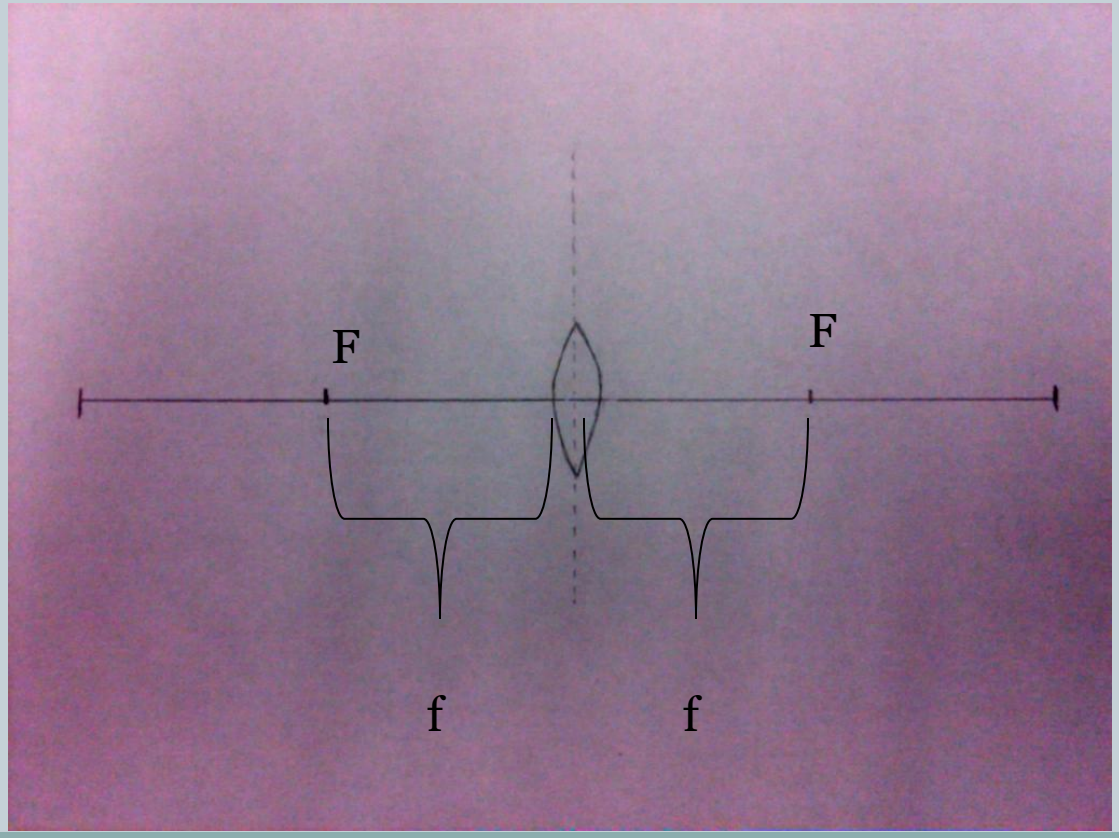

Vertical axis
Principle axis

- Light rays passing through a converging lens will converge (come together) at a specific point.
- This point is known as the **focal point** of the converging lens.
- The focal point is denoted by the letter **F**.
- Unlike mirrors, lenses can allow light to pass through either face, depending on where the incident rays are coming from. Subsequently, every lens has two possible focal points.

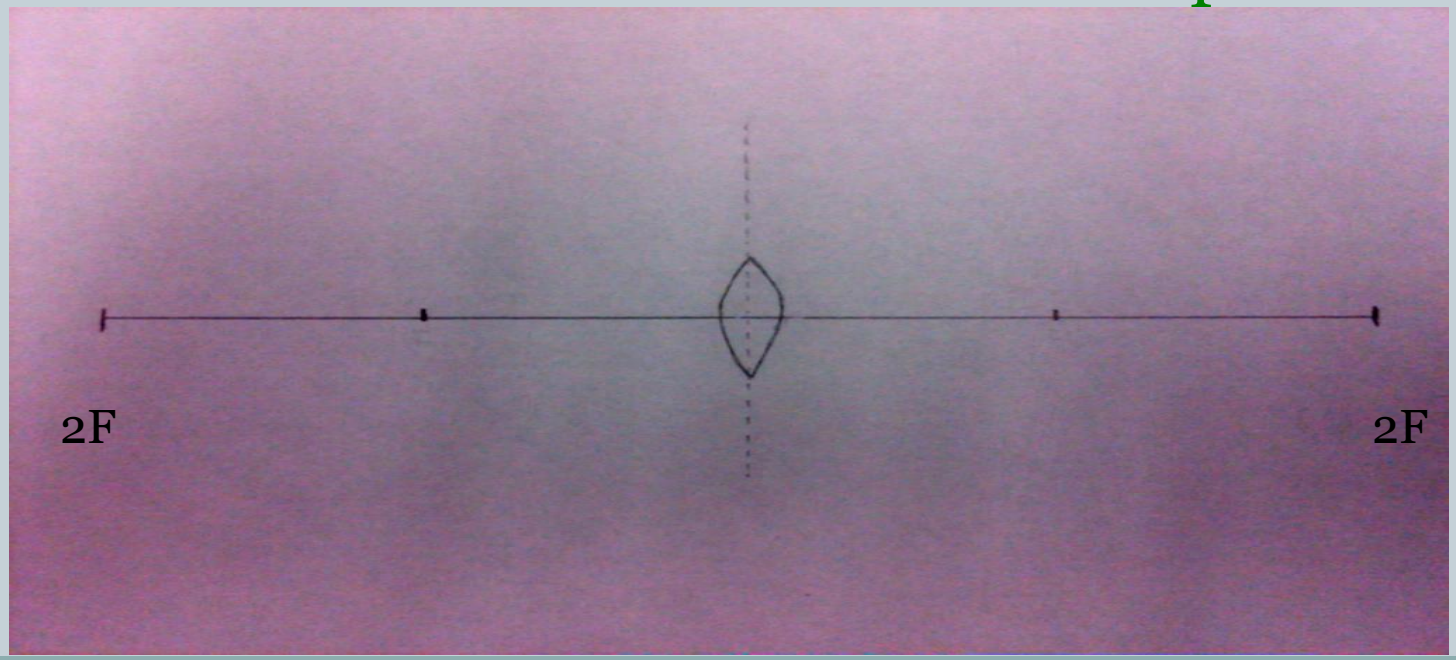
- Need drawing of focal point with lens



- The distance from the vertical axis to the focal point is known as the **focal length** (abbreviated by "**f**").



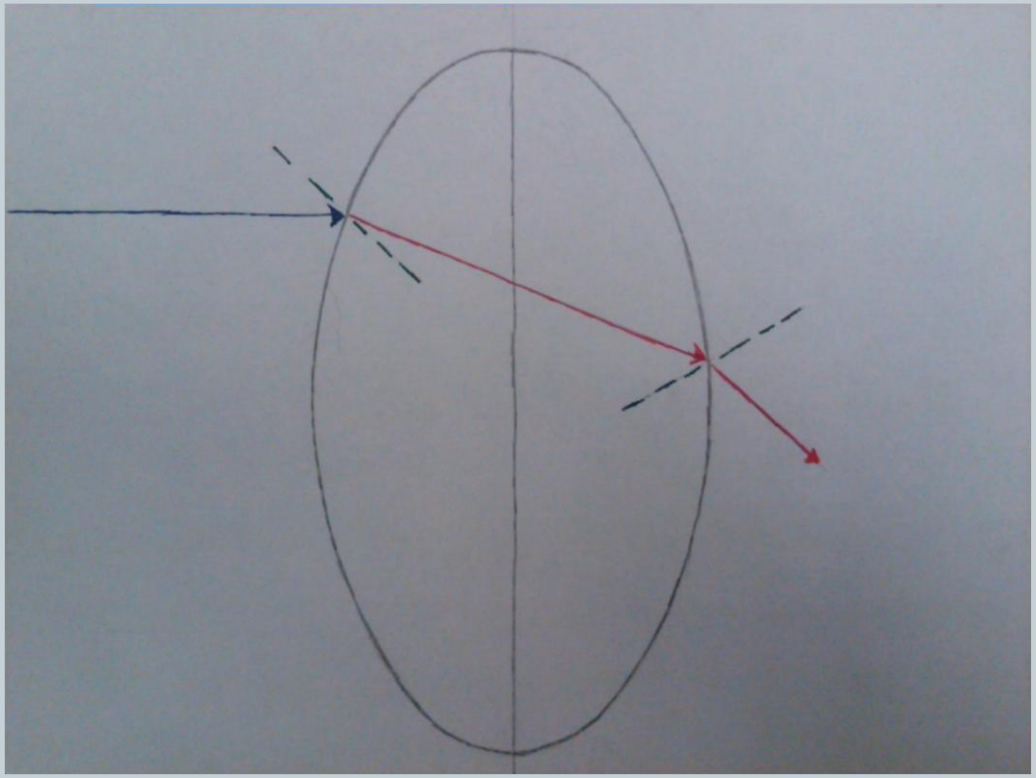
- A converging lens has an imaginary point which we refer to as the **2F point**.
- This is the point on the principal axis which is twice as far from the vertical axis as the focal point is.



- When light crosses a boundary from one material into another the ray will bend.
- **Refraction**: The change in direction of a wave (bending) as it crosses the boundary between two media in which the wave travels at different speeds.
- When light refracts, it also changes velocity.
- We consider space to be the least optically dense material and air a close second. So when light travels through something more optically dense than air the wave will slow down.

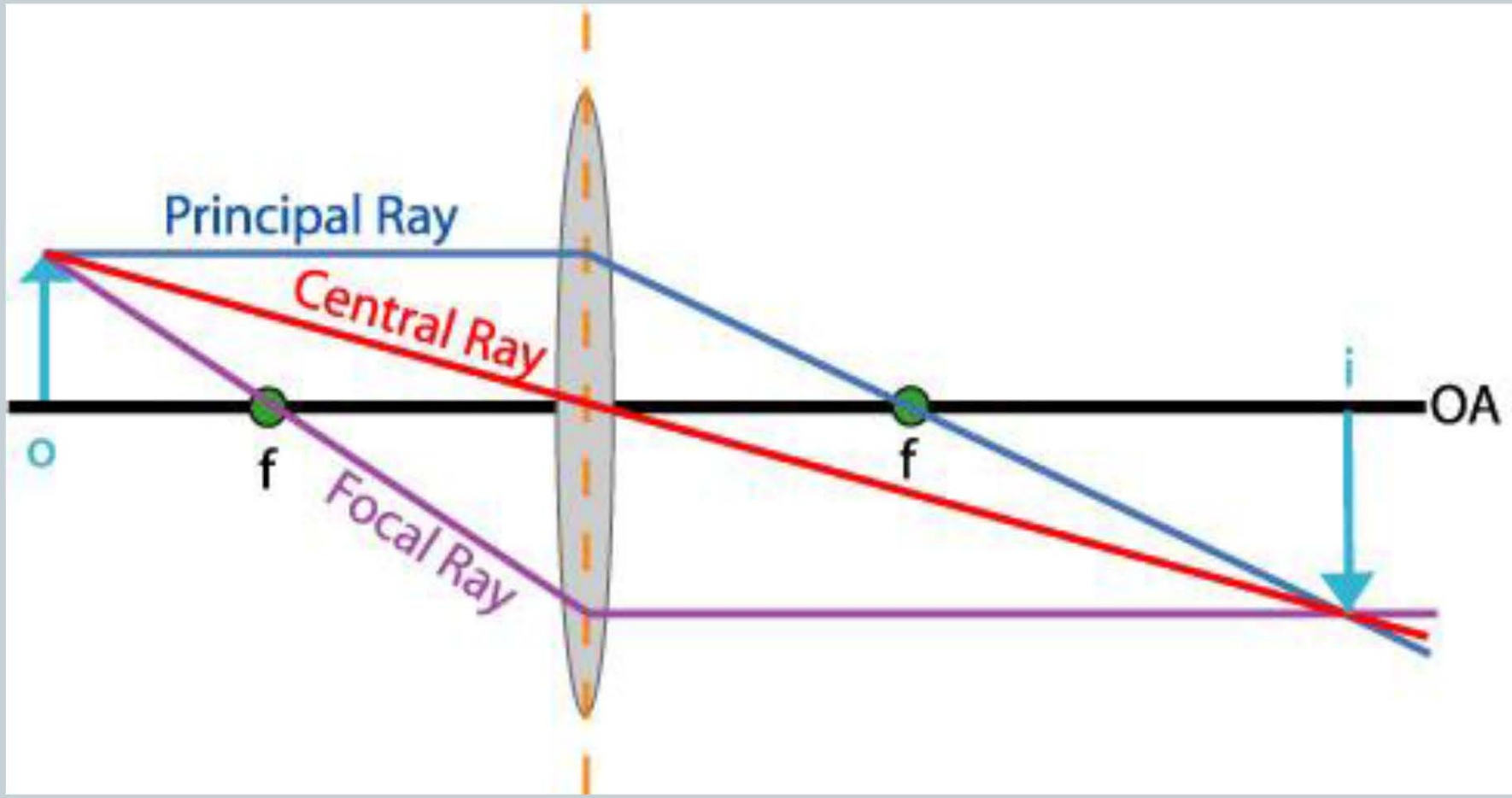
- When the wave slows down it bends towards the normal.
- The Normal is a line drawn perpendicular to the surface at the point the wave meets the surface.

- A simple sketch of refraction through a double convex lens.



Refraction Rules for a Converging Lens

- Any incident ray traveling parallel to the principal axis of a converging lens will refract through the lens and travel through the focal point on the opposite side of the lens.
- Any incident ray traveling through the focal point on the way to the lens will refract through the lens and travel parallel to the principal axis.
- Any incident ray which passes through the center of the lens will in effect continue in the same direction that it had when it entered the lens.



- Image courtesy of NASA

The thin lens equation

- This equation expresses the quantitative relationship between the object distance (d_o), the image distance (d_i), and the focal length (f). The equation is stated as follows:

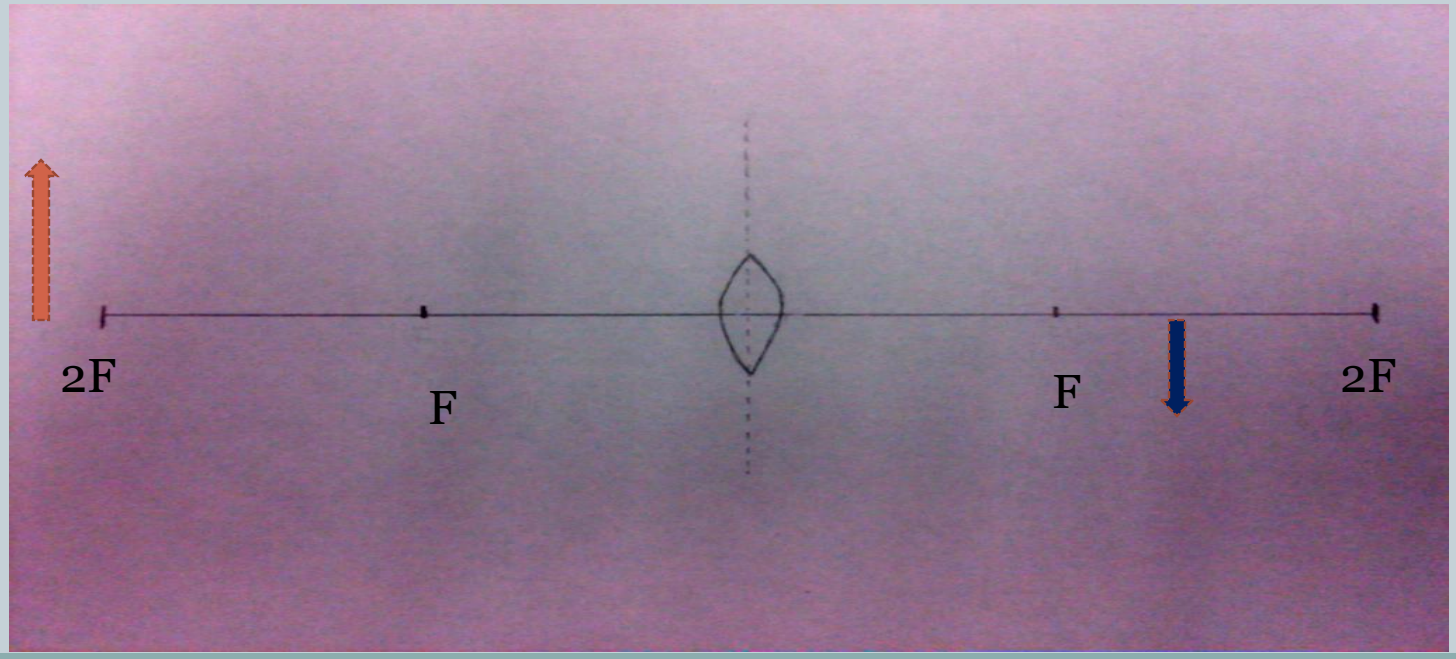
$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

- At this point, lets experiment with a double converging lens and see what kind of images we can form.
- We will need the lens, the optics kit and a meter stick.

- So, how many different kinds images were you able to find during the experiment?
- Hopefully you found 4 real images or images formed from converging light rays.
- There are actually 5 possible images, but the 5^{th} one is a virtual image.
- Lets look at the following slides for an explanation.

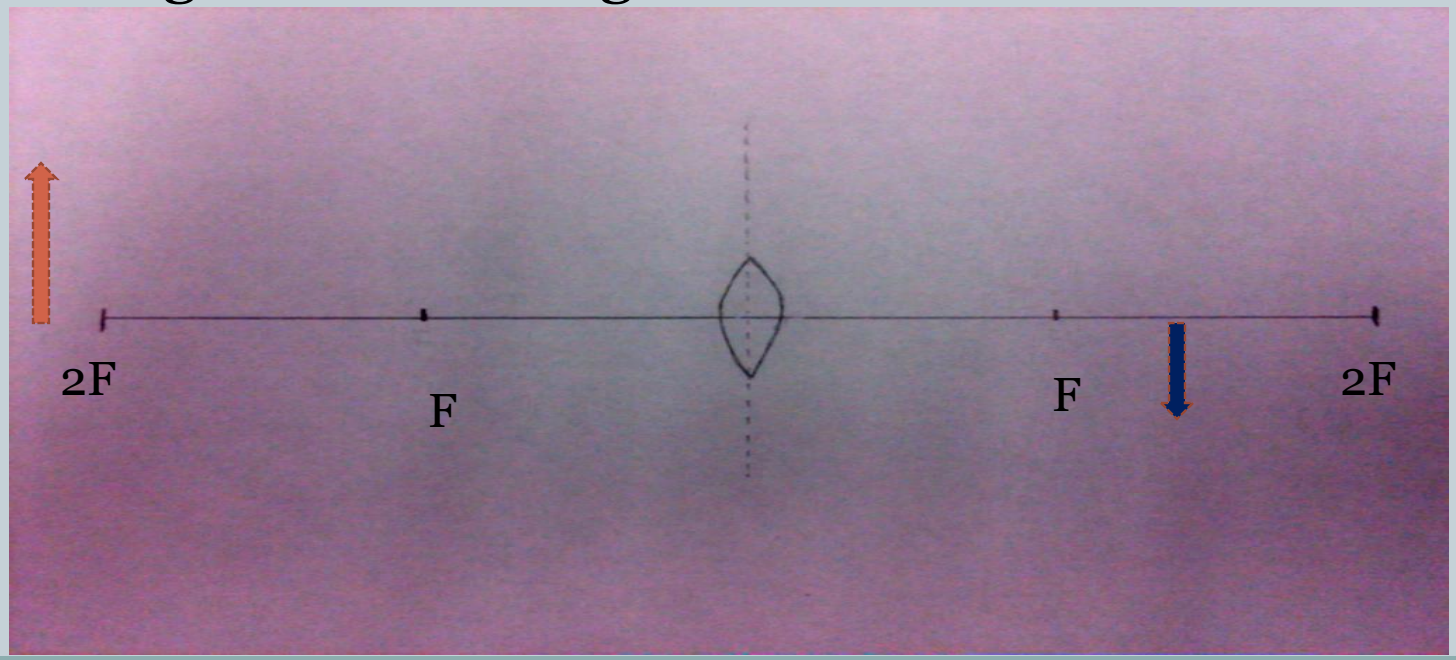
Case 1: The object is located *beyond* 2F

- When the object is located at a location beyond the 2F point, the image will always be located somewhere in between the 2F point and the focal point (F) on the other side of the lens.



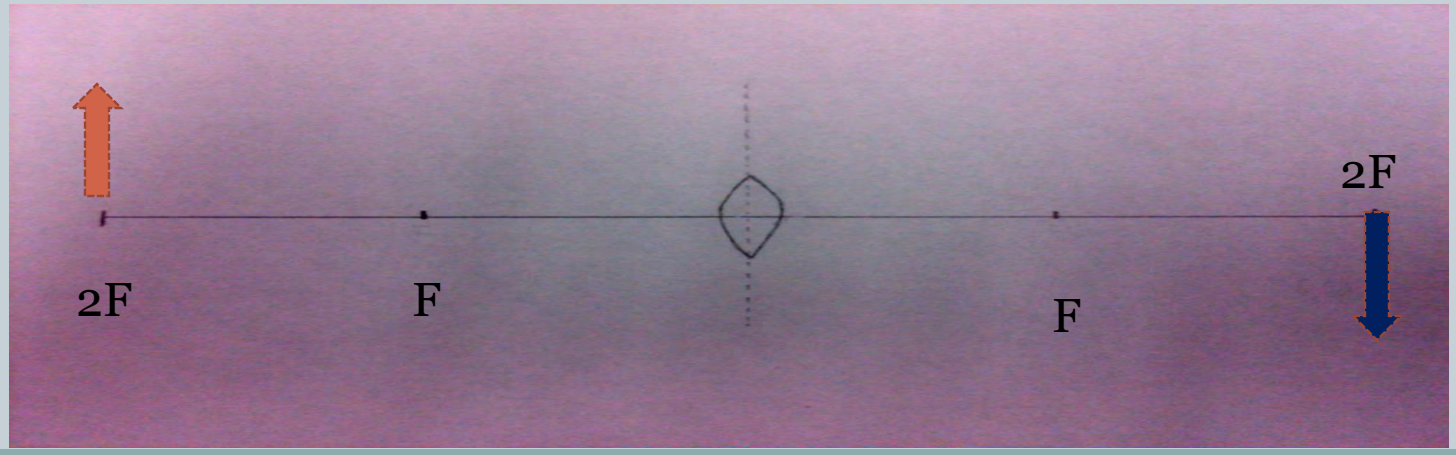
Case 1: The object is located *beyond* 2F

- In this case, the image will be an **inverted image**. **reduced in size,** the **magnification** is the ratio of the height of the object to the height of the image. In this case, the magnification is a number less than 1. Finally, the image is a real image.



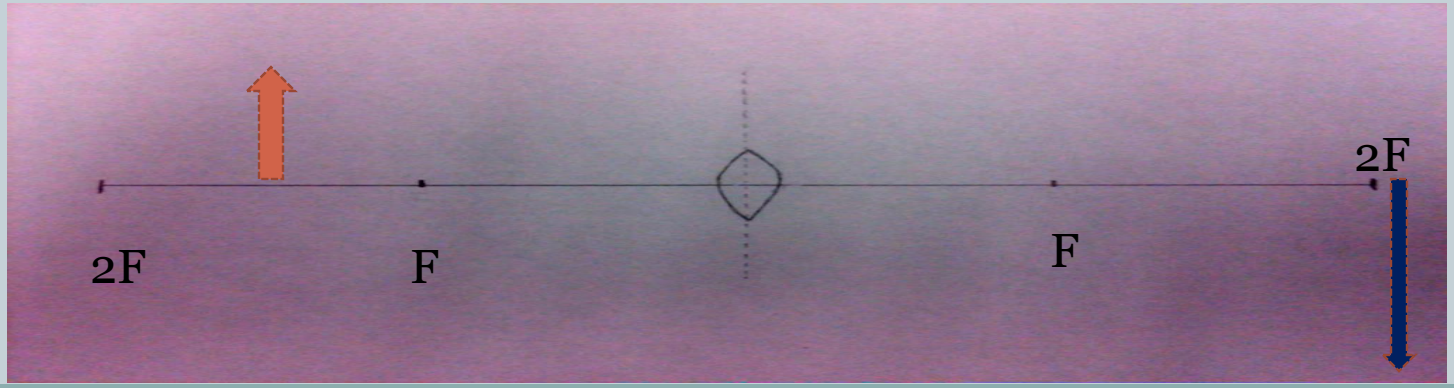
Case 2: The object is located at 2F

- When the object is located at the 2F point, the image will also be located at the 2F point on the other side of the lens. the image will be inverted, The image dimensions are equal to the object dimensions, magnification is exactly 1, Finally, the image is a real image



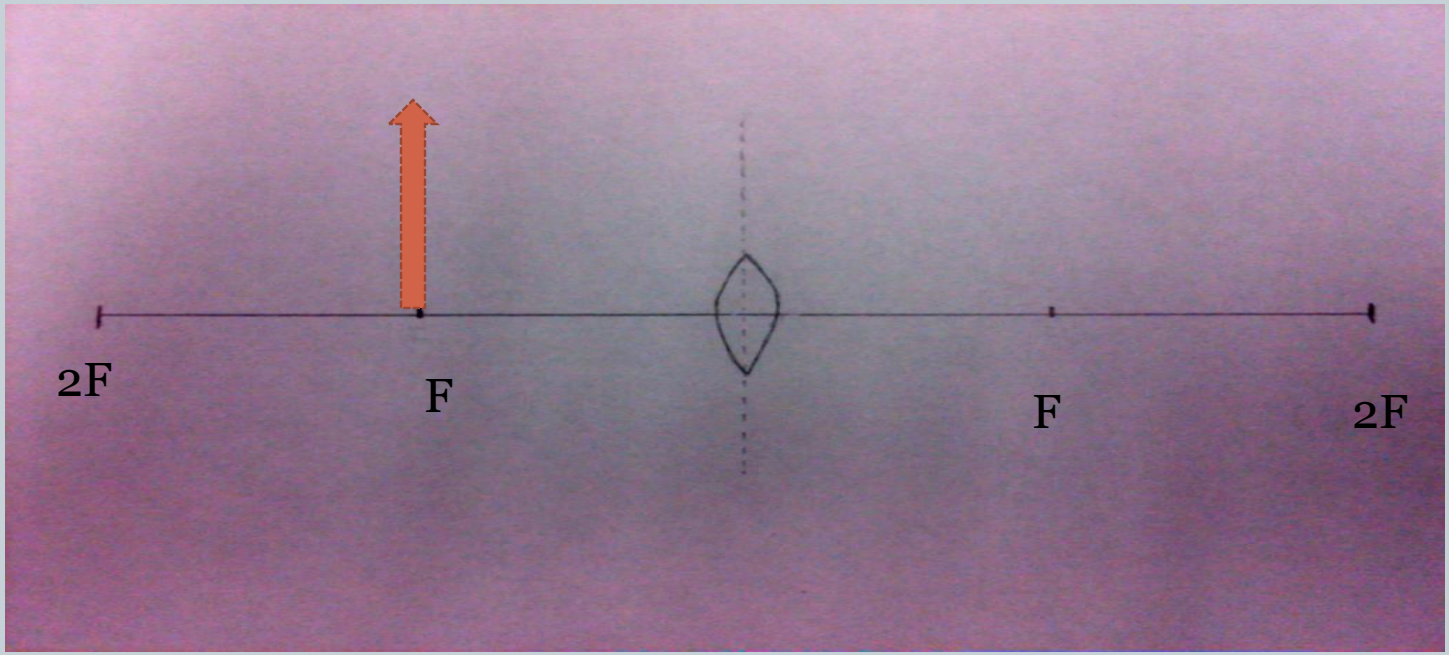
Case 3: The object is located between 2F and F

- When the object is located *in front of* the 2F point, the image will be located *beyond* the 2F point on the other side of the lens.
- In this case, the image will be inverted, The image dimensions are larger than the object dimensions. the magnification is greater than 1. Finally, the image is a real image



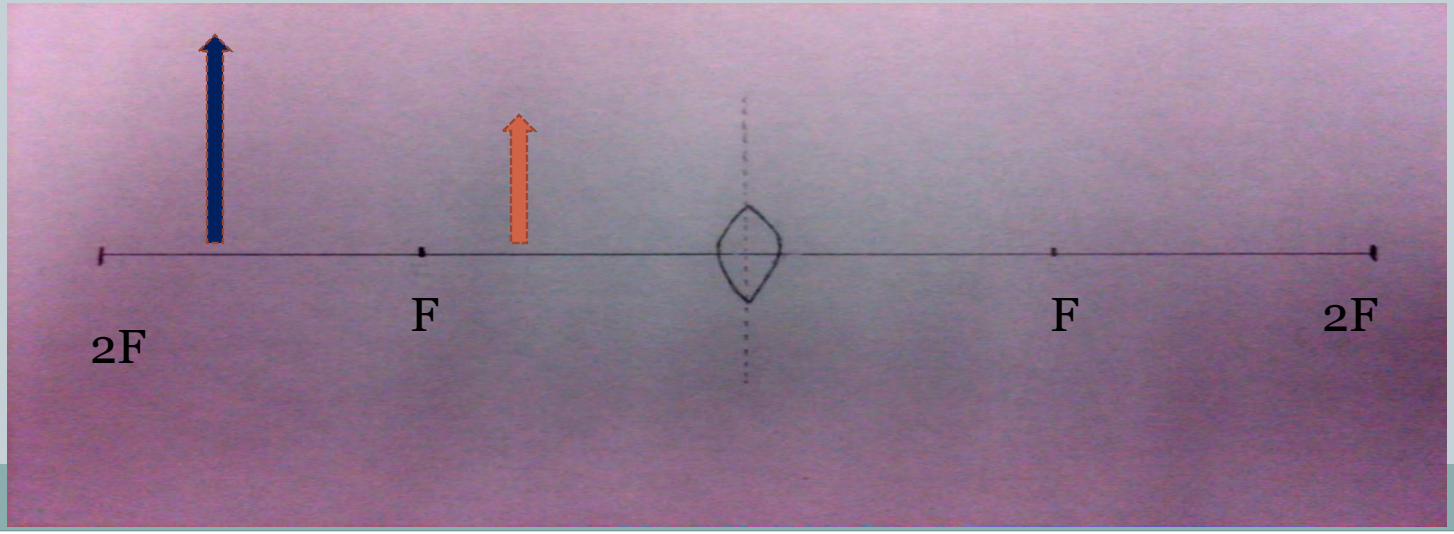
Case 4: The object is located at F

- When the object is located at the focal point, no image is formed



Case 5: The object is located *in front of* F

- When the object is located at a location beyond the focal point, the image will always be located somewhere on the same side of the lens as the object.
- the image will be an **upright image,** the image is **enlarged,** the magnification is greater than 1. Finally, the image is a virtual image.



- So, having looked at the converging lens and the flat mirror and the camera obscura, can you think of any practical applications for these instruments?

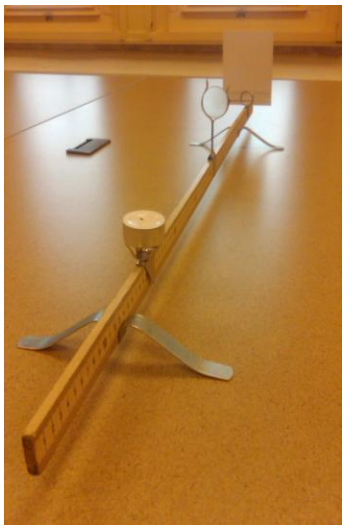


Image Formation with a Converging Lens

Purpose: To verify the thin lens formula, to investigate the properties of a converging lens, including the magnification, and to verify the object-image distance formula for spherical mirrors.

Discussion: The thin lens formula is, $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$

and the magnification formula is, $m = \frac{h_i}{h_o} = \frac{d_i}{d_o}$

h_o : object height h_i : image height
d_o : object distance d_i : image distance

For a converging lens, f is assumed to be positive. If the object is real, d_o is also positive.

Procedure:

1. First set the apparatus up as seen in the top left picture. The meter stick sits in the two stands, the candle sits in the candle holder the lens in the lens holder and the card stock (screen) in the card holder all on top of the meter stick. Once the apparatus is set up we will turn down the lights in the laboratory.

2. Place the candle near the zero end of the meter stick. The object will be the flame. Write down its position as x_o. You may keep the position of the object constant throughout the experiment. Measure h_o the height of the object.

3. Position the recommended lens at some intermediate position x_L.

4. By moving the white screen, determine x_i the position of the image. Calculate the object distance [$d_o = x_L - x_o$] and the image distance $d_i = [x_i - x_L]$. Calculate $1/d_o$ and $1/d_i$.

5. Measure h_i the height of the image. **Note** that an inverted image has a negative height! Calculate the observed magnification h_i/h_o and the theoretical magnification - d_i/d_o. Do they agree? Calculate a percentage difference.

6. Repeat steps 2-5 for a range of possibilities. Make sure you cover the entire range of object distances which will create a real image!

    a. How many images were you able to form?

    b. Make a chart that lists the location of the flame, the lens and the image for each of the images you found, as well as the height of the flame and of each image and whether it was inverted or not.

7. Make a graph of $1/d_i$ versus $1/d_o$.

    a. Do you get a straight line?

    b. What are the slope and intercept? (According to the thin lens formula the slope should be -1 and the intercepts should be 1/f.)

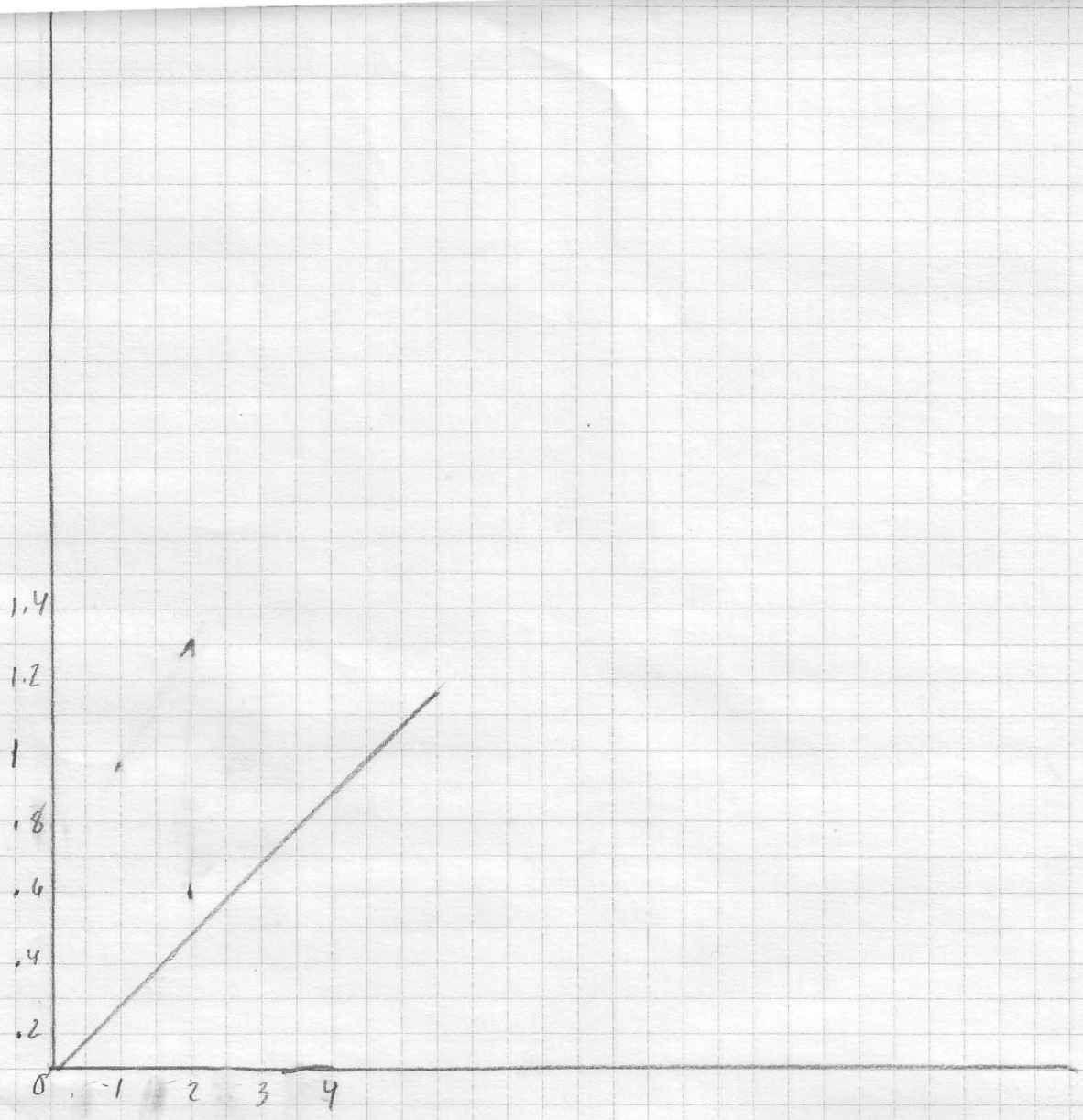
    c. Use your intercept to calculate the focal length f.

8. Make a graph of the theoretical magnification - d_i/d_o on the Y- axis vs. the observed magnification h_i/h_o on the X-axis. Make your axes with the same scale. Your data points should fall on a line inclined at 45° to the horizontal axis. Draw this line on your graph so that you can see how close to it your points are.

Extension

Set up the object, lens and screen so that you form an image on the screen. Predict what you would observe on the screen if you now cover the lower half of the lens with an opaque screen. Perform this activity and record your observations. How do you explain what you have observed?

Predict what you would see if you covered three-fourths of the lens with an opaque screen. Perform this activity. Record what you have observed. How do you explain your observation?


-di/do
1.4
1.2
1
.8
.6
.4
.2
0
1
2
3
4
hi/ho

location	d_i	d_o	f	h_i	h_o	M	$1/d_i$	$1/d_o$	$-d_i/d_o$	$-h_i/h_o$
2F	0.41m	0.36m	0.19	0.017m	0.017m	1	2.44m	2.78m	1.14	1
between 2F + F	0.34m	0.28m	0.18	0.0328m	0.017	1.93	1.85m	3.57m	1.93	1.93
between 2F + F	0.62m	0.25m	0.18	0.046m	0.017	2.68	1.49	4.0	2.68	2.68
focal point	N/A	0.19m	0.19m	N/A	0.017	N/A	N/A	N/A	N/A	N/A

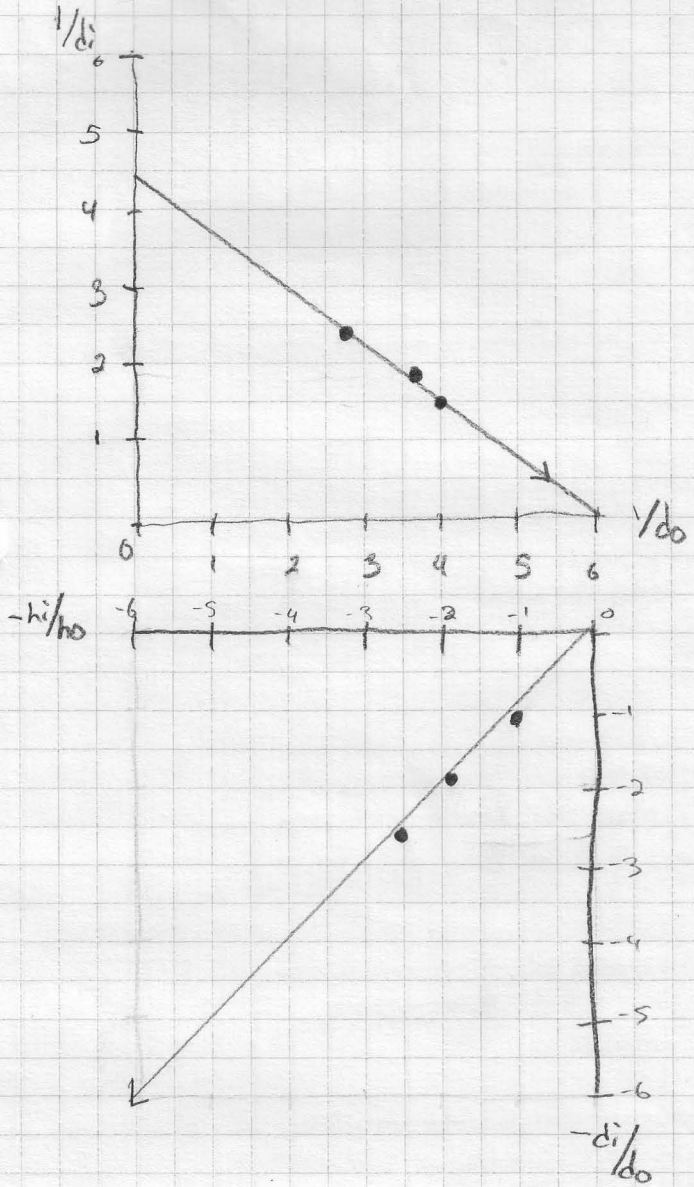
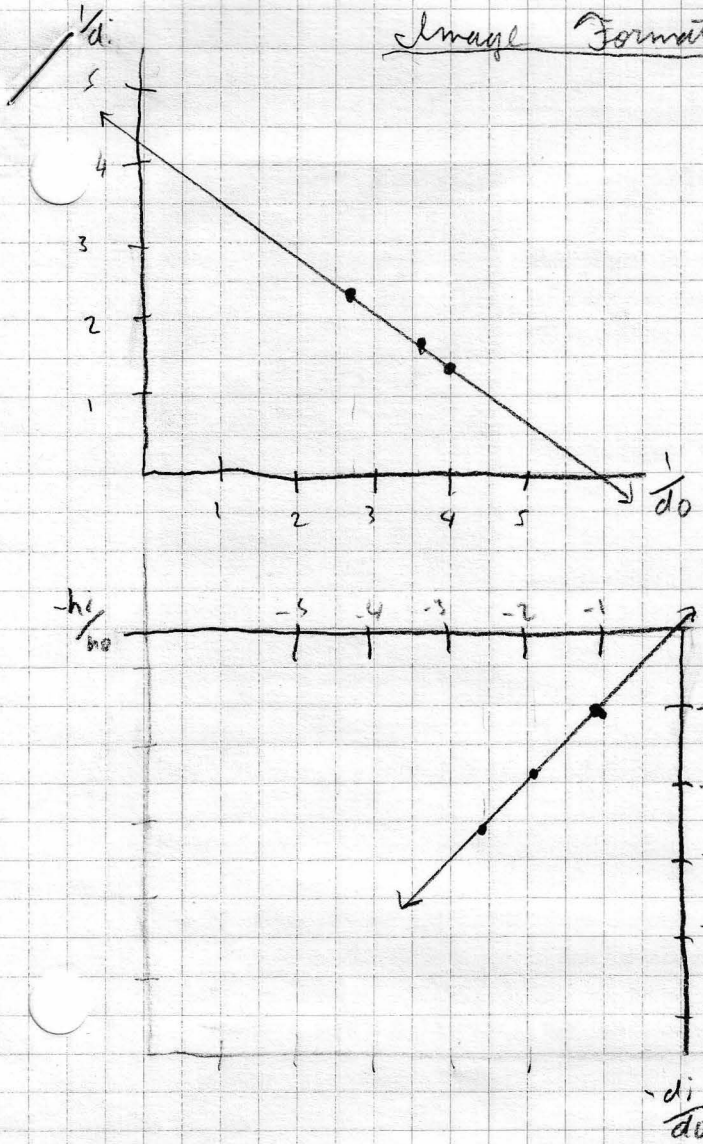
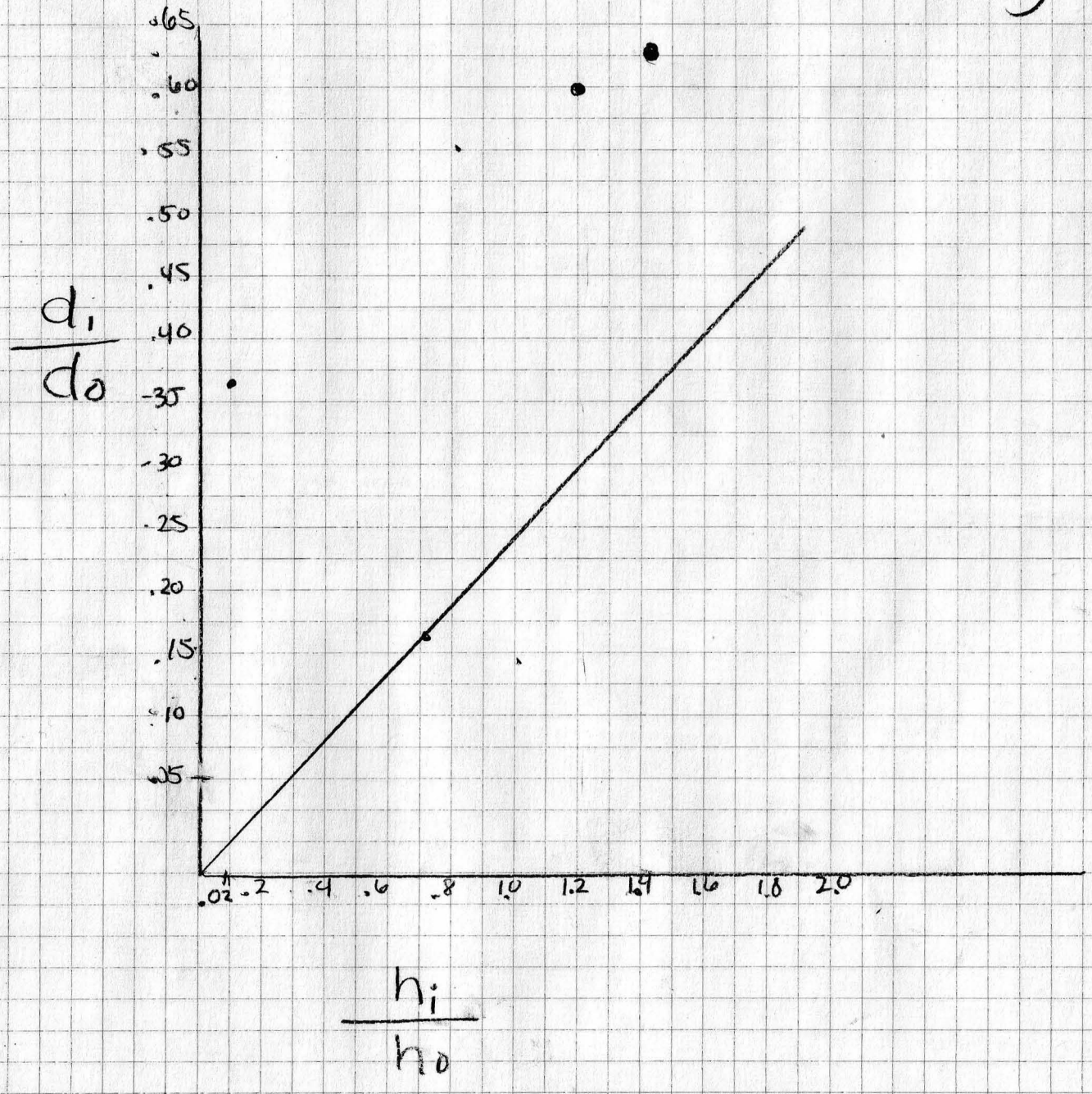


Image Formation With a Converging Lens

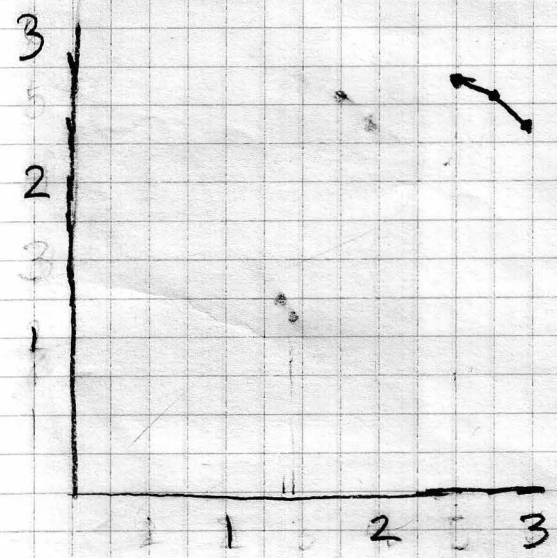


							L		L	
							y	x	y	x
Location	di	do	f	hi	ho	M	1/di	1/do	-di/do	-hi/ho
2F	0.41 m	0.36 m	0.193	0.017	0.017	1	2.4	2.78	1.14	1
between 2f + F	0.54 m	0.28 m	0.185	0.0328	0.017	1.93	1.85	3.57	1.93	1.93
between 2f + F	0.67 m	0.25 m	0.182	0.045	0.017	2.69	1.49	4.0	2.68	2.68
focal point	~~N/a~~	0.18	0.18	~~N/a~~	0.017	~~N/a~~	~~N/a~~	~~N/a~~	~~N/a~~	~~N/a~~

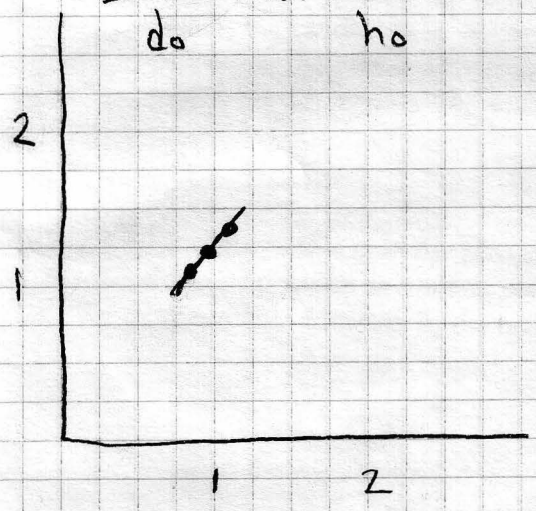
Magnification



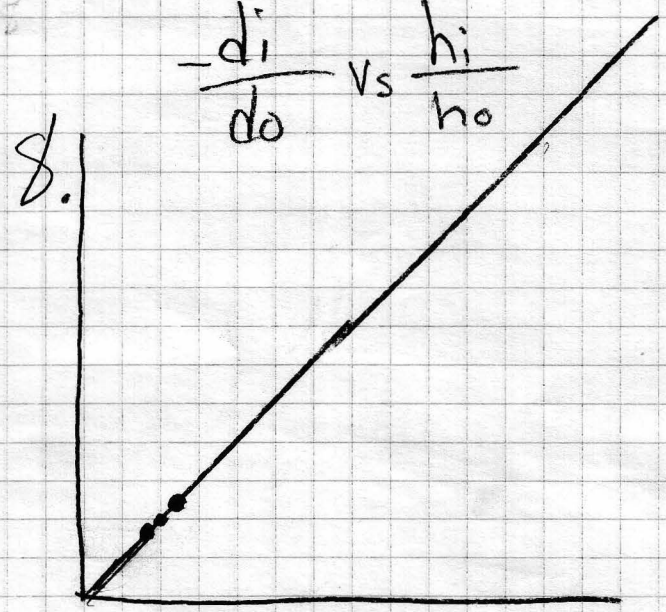
$1/d_i$ vs $1/d_o$

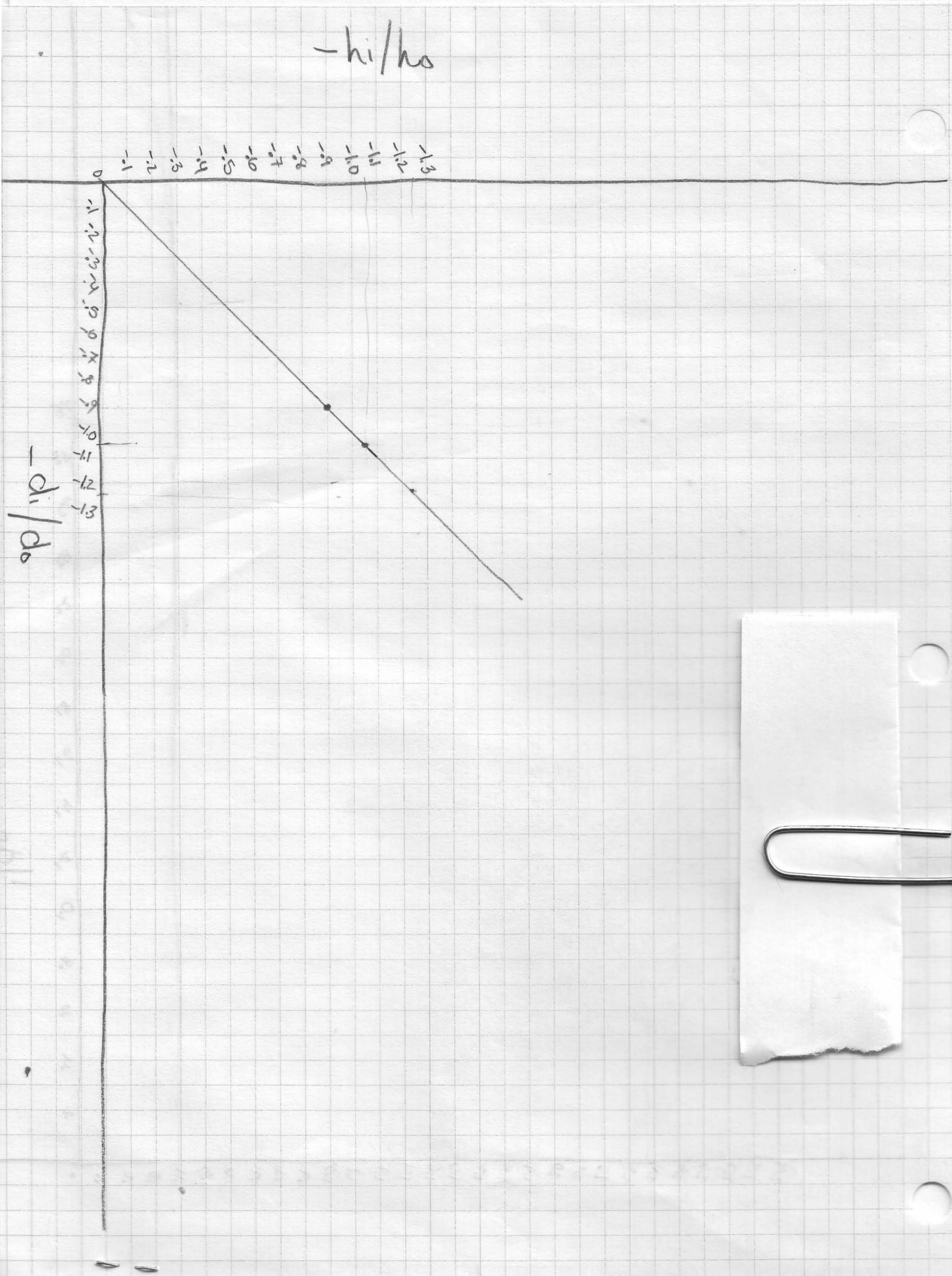


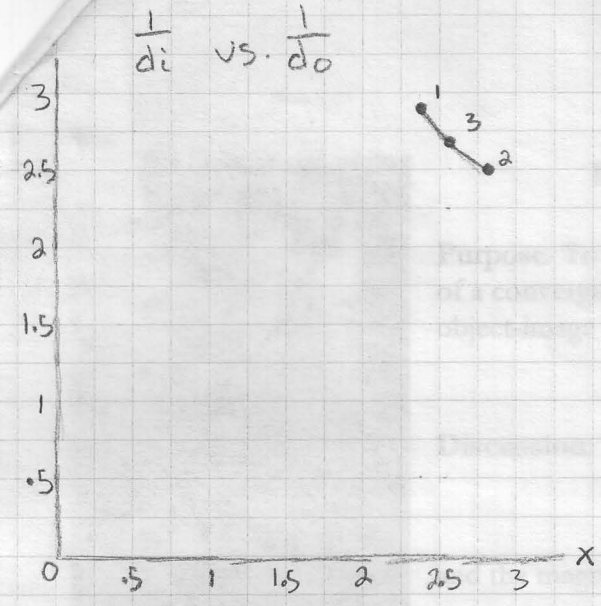
$\frac{d_i}{d_o}$ vs. $\frac{h_i}{h_o}$

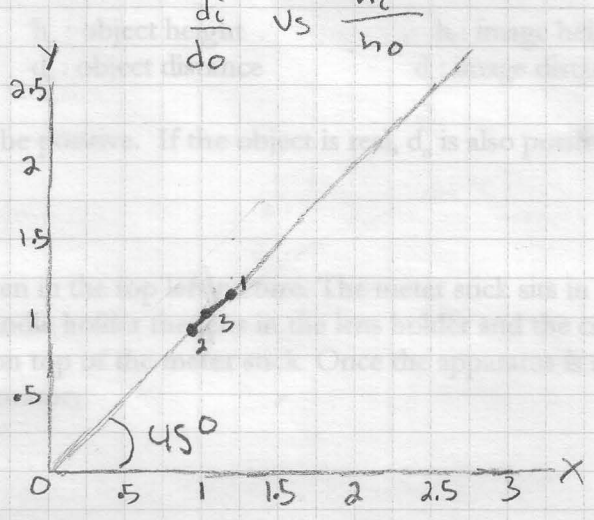


$-\frac{d_i}{d_o}$ vs $\frac{h_i}{h_o}$




-hi/ho
0
-.1
-.2
-.3
-.4
-.5
-.6
-.7
-.8
-.9
-1.0
-1.1
-1.2
-1.3
-di/do





etely

23.5% = percentage difference

-1.235 - (-1) = -.235

SCIENTISTS, ARTISTS AND THE CAMERA OBSCURA

- Looking back in history, can you think of any scientists that would have used mirrors, lenses and / or a camera obscura?
- I’m sure you’ll remember the following Scientists from previous classes.

Aristotle

- Aristotle referred to a device like a camera obscura in 350 BC in his writing *Problemata*.
- He used the apparatus to observe the sun, and made note of the fact that no matter what the shape of the hole was the sun would still be correctly displayed as a circular image. E also made not that when he increased the distance between the hole and the “screen” the image would be amplified.

Galileo

- Built a telescope and studied the stars.

Antony van Leeuwenhoek

- Leeuwenhoek is known to have made over 500 "microscopes," of which fewer than ten have survived to the present day.

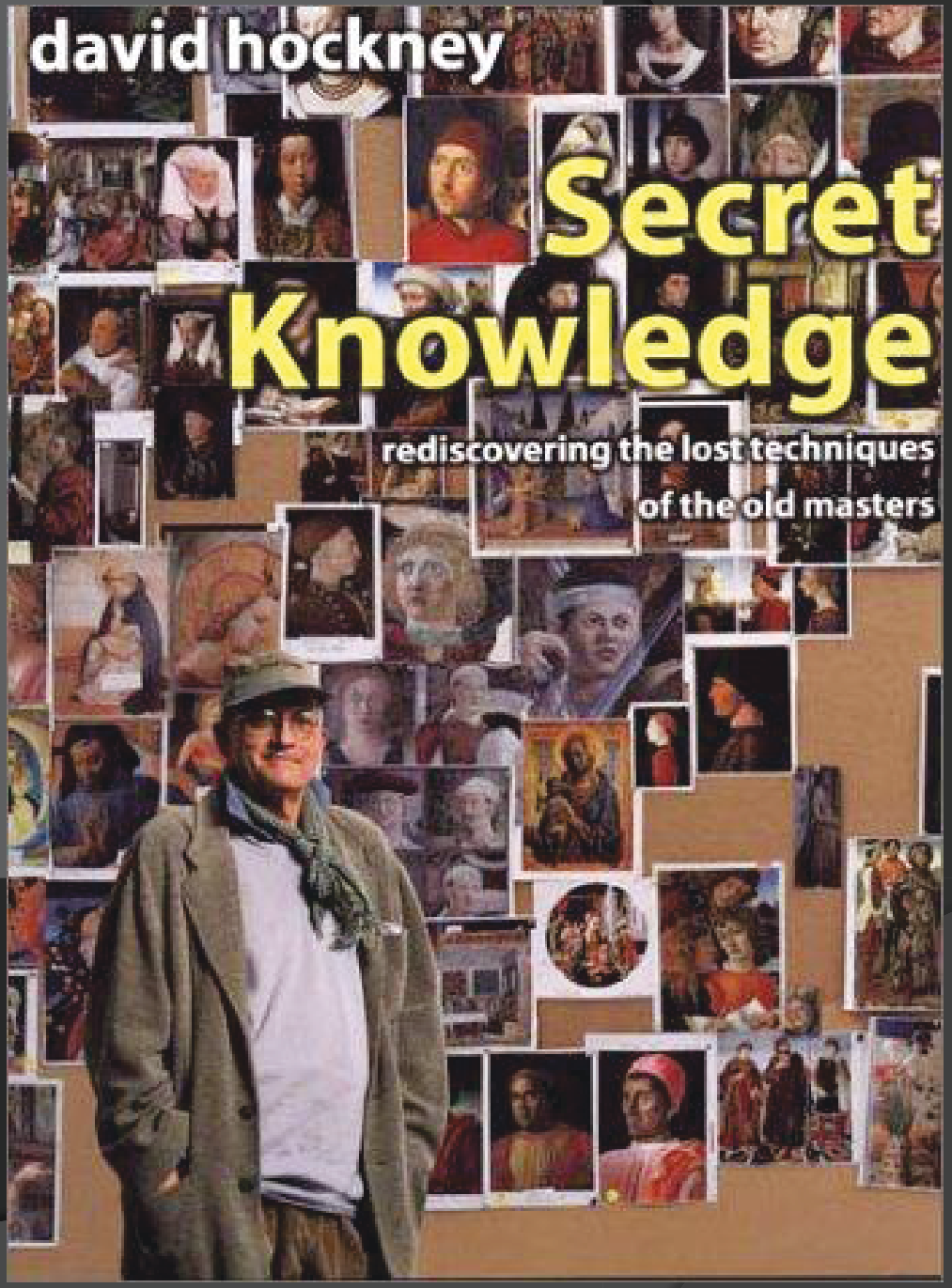
- What about other professions?
- Do you think lenses or mirrors were used by anyone outside the science community?

- Here is a microscope on display in gallery 216 of the CMA.
- This is from France from the mid 18th century.
- This is a beautiful example of the joining of art and science.

- A modern day artist by the name of David Hockney conducted a study on art and optics made some interesting observations about artists of the past and their possible use of optics.

- He admits though, that with no hard evidence, his conclusions are not absolute but rather a possibility.

- Secret Knowledge, rediscovering the lost techniques of the old masters, David Hockney



- His visual evidence is a collection of paintings and a discussion on how he believes the painters accomplished their work with the use of optics.
- He even conducts a few experiments himself, with amazing results.
- Lets take a look at some of his conclusions.

- First, he discusses the amazing attention to detail that transpired over several hundred years.
- He suggests that the use of optics aided artists in duplicating the detail in material.
- The following slides show excerpts from his book outlining his ideas on optics and their use centuries ago.

The Marriage at Cana by Giotto (c. 1303-05)

Notice the detail on the garments and the facial features.

The year is roughly 1303.

Pisanello, approximately 1438

Again, notice the detail on the garments and the facial features.

Giovanni Battista Moroni 1553

Again look at the detail on the garments and the facial features.

Hockney argues that it is possible that later artists had far superior talent to earlier artists or it's possible they used optics to aid in their art.

Andrea del Castagno
1448

Saints Anthony and George, Pisanello 1450

Look at proportions and garments.

St. George, Andrea Mantagna 1460

Notice the armor, face and hands

Warrior with Shield Carrier by Giorgione 1501

Notice the detail and only a 40 to 50 year difference!

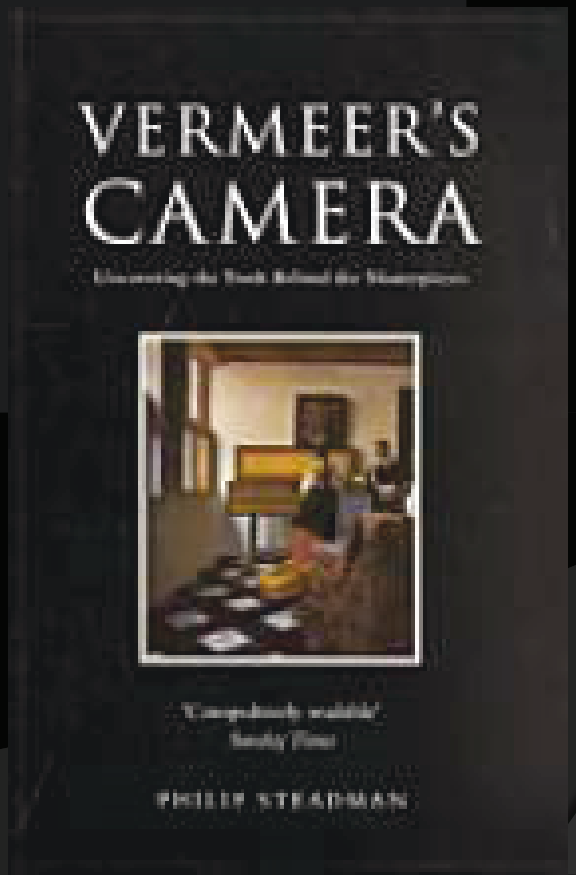
King Phillip II by Antonis Mor 1557

Portrait of a member of the Balbi family, Anthony van Dyck

Hans Holbein 1532

Notice the left corner of the table moving inward towards the letter, the table seems to “move up” yet the can of coins looks as if it is about to spill over. This suggests the use of optics, perhaps the lens was moved.

- Philip Steadman's new book, *Vermeer's Camera*, analyses ten paintings. Each shows exactly what one would've seen from a single point. These are literally views through a pinhole camera. They could be photographs.



- This book talks about Vermeer’s possible knowledge of optics.
- Steadman also recreated Vermeer's studio including a camera obscura!
- Like Hockney, Steadman is not trying to demean the artists extraordinary talent. Instead he demonstrates how, the artist may have experimented with new technology to develop his unique style and choice of subject matter.

Allegory of the Catholic Faith,
Johannes Vermeer

- So what would the set up look like to create this kind of work *if* we were going to use optics?

Here is a French Camera obscura I found on line. It has directions pasted to the bottom that give directions on how to focus the camera and trace the image.

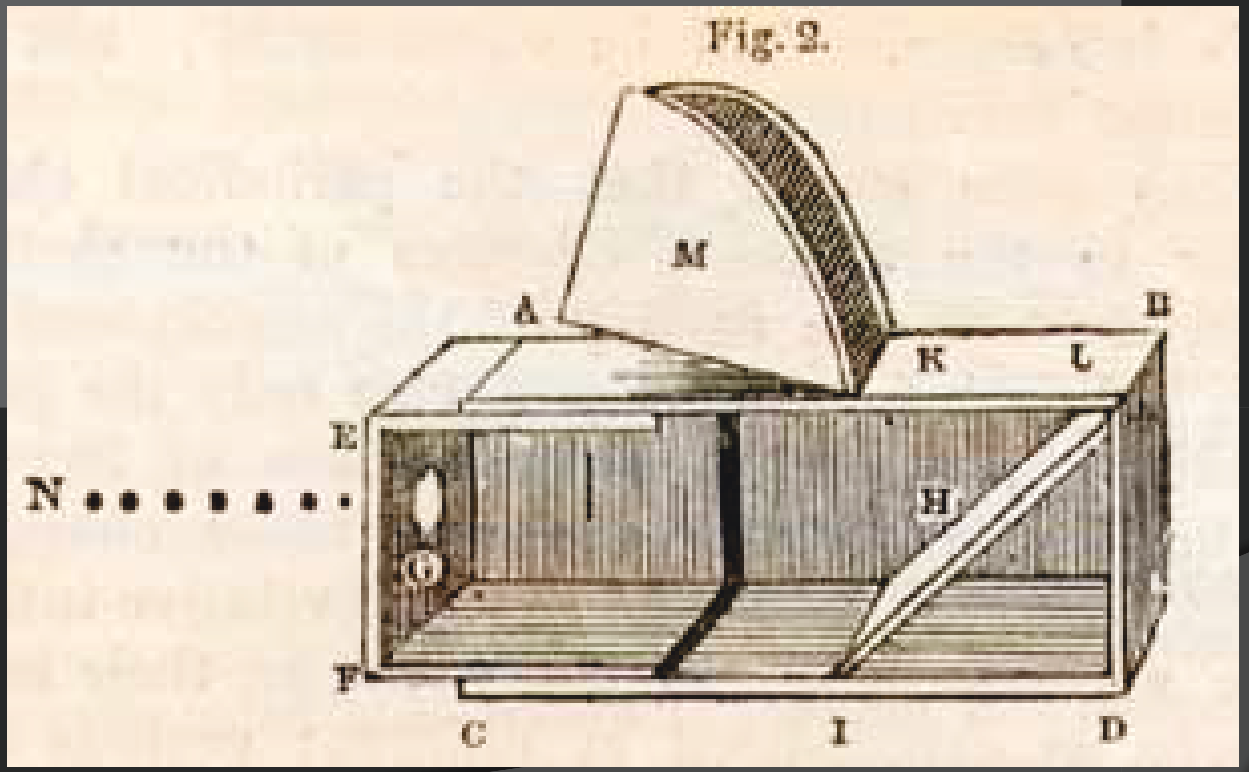
Supposing there is a lens in the tube sticking out the side, what do you think is inside the box?

Where would you put the paper in order to trace the image?

The directions also say to cover your head with a dark cloth in bright light.

- Here is another I found. In this picture you can see the lens.

- Here is a sketch of what the inside looks like. What do you think the slanted piece Labeled H is?



Here are some variations on design that I found.

The artist would actually sit inside of these two.

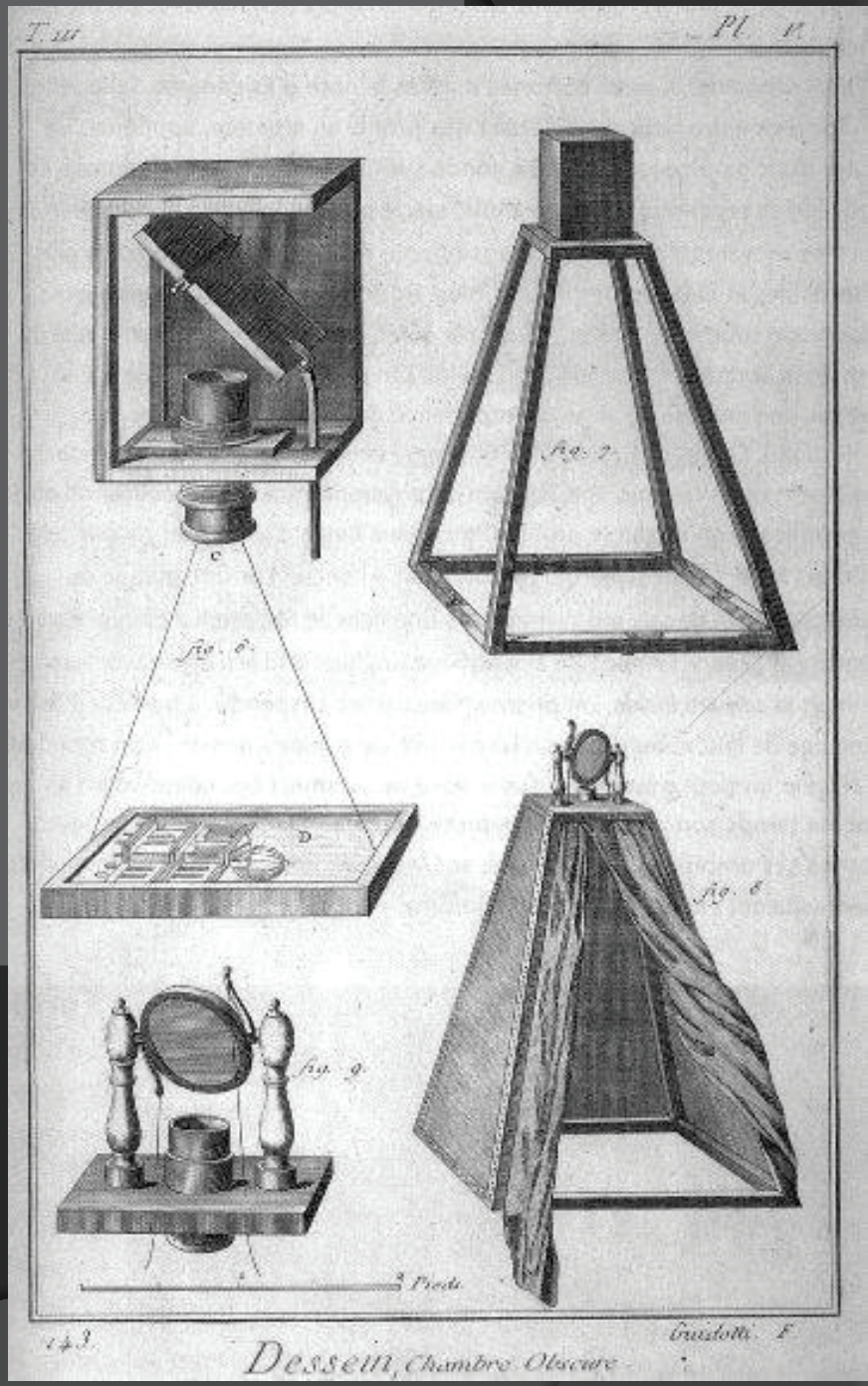


Fig. 204.

IMPROVED CAMERA OBSCURA,

For the instruction of Youth in the Art of

DRAWING & COLORING.

By this Instrument, persons unacquainted with Drawing, are enabled to take an exact likeness of anything they desire. By these means Mr. West, the Historical Painter became possessed of his splendid talents (see London Magazine 1819)

DIRECTIONS FOR USE.

Place on the Transparent Slate a piece of tracing or fine Bath paper, then present the Instrument to the object intended to be taken, when it will be reflected on the paper, then follow the lines with a pencil and you will have a correct likeness of the view desired, if a profile or Portraut, place the person in a strong light till you have a clear detail of the features then follow the directions before mentioned and you will have a correct representation of the original.

N.B. If placed in a position so as to reflect objects in motion it will represent a beautiful panorama of animated nature.

RAY, Inventor & Manufacturer, *Red Lion Passage, Holborn, London.*

Musical Boxes, Clock Work, and Automaton figures Repaired.

Here is an advertisement for a camera obscura for the purposes of drawing and coloring.

- Finally lets look at an American Painter named Benjamin West.
- He painted historical scenes around the time of America's independence.

Here is a painting of King George III of England, painted by Benjamin West.

It hangs in gallery 204 in the CMA

- Henry E Jackson wrote a book titled: Benjamin West His life and Work.
- In this book on page 38 Jackson tells a story about West being sick in bed with the windows shut tight and seeing a cow and then some pigs walk across the ceiling.

- He later finds there was a small hole in the shutter that allowed light to enter the room.
- From this discovery according to Jackson, he builds a camera obscura.
- There is speculation that West used a camera obscura with some of his art.

THE END

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CMA Activity

You will be given a list of 3 paintings and their gallery location in the Cleveland Museum of Art. Your job is to locate these 3 paintings and spend some time observing them. Your goal is to decide which of the 3 on your list might have been painted with the aid of an optical device. During your observations you should take detailed notes on your thoughts, you can also make a sketch of the painting or portions of the paintings to support your conclusions. In a short one to two page paper discuss the 3 paintings you observed and outline your reasons for which painting you have chosen to have been created with the aid of an optical instrument. Be specific in your analysis and discussion. Once your paper is complete, create a power point with your 3 paintings from the CMA online collection and present your conclusions to the class.

CMA ACTIVITY LIST 1

British Manufactory; A Sketch,

Benjamin West

gallery 204

A Musical Company

Jacob Ochtervelt

Gallery 213

Portrait of Tieleman Roosterman

Frans Hals

Gallery 213

CMA ACTIVITY LIST 2

Portrait of the Jester Calabazas,

Diego de Velázquez,

gallery 212

Portrait of Elizabeth Spiegel

Dirck Dircksz. Santvoort

Gallery 213

Esther, Ahasuerus, and Haman

Jan Steen

Gallery 213

CMA ACTIVITY LIST 3

The Crucifixion of Saint Andrew

Caravaggio

Gallery 217

Portrait of a Woman

Gerard Terborch II

Gallery 215

Portrait of a Family Playing Music

Pieter de Hooch

Gallery 213

4-8-11

CMA Activity

For hundreds of years countless artists have created detailed paintings. After studying art from different time periods, speculation has been made about the methods people used in creating these paintings. As the works of these artists are examined, you can notice a significant difference. It seems as though some early paintings have a noticeable variance in detailing and proportions of the body. Facial features seem to be too small or out of proportion to the head or remainder of the body. Hands and other extremities seem to be off in size. The details in clothing and surrounding objects also appear to be more simplistic. As you examine paintings of later dates, facial features and expressions appear more individual. Parts of the body also look more in proportion compared to early paintings. There are many more details shown in clothing and other objects. Because of this, it has been questioned whether or not later artists used technology to aid them in their work. People have speculated as to whether or not the artists used optical devices to improve their work. My goal is to determine which of three paintings assigned to me has been created with an optical device.

The painting I shall first discuss is called A Musical Company. It was painted by Jacob Ochtervelt in 1668. As I look at this painting, the first thing I notice is the face shape of the woman in the center. Her face appears very round and large compared to the facial features. Her hands also appear to be very small in comparison to the rest of her body. This is also noticeable when you observe the woman in the background. There are some nice details in the clothing and items in the backdrop, but there are not too many. You can see a design on the sash the man at the left is wearing. There are also some patterns in the woman's red dress on the trim, but there are not too many details in the clothes. The picture also shows some details in the background with an ornate mirror and some paintings on the wall. However, in comparison to the other paintings, I do not believe this to be the one created using an optical instrument.

The next picture is called Portrait of Tieleman Roosterman painted by Frans Hals in 1634. This painting, as it is a portrait, seems to be more individualized in the facial features. The man's facial features and hands seem to be more in proportion than the last picture. There are some, but not too many details in his clothing. You can see the detailing on the lace of his collar and cuff. There are also fine points on the belt. However, the clothes are not very ornate and detailed like those of paintings that have been questioned to have been created using an optical device. As I compare the three paintings, I do not believe this to be the one made using an optical device.

The final painting is called British Manufactory; A Sketch by Benjamin West. It was painted later than the others in the year of 1791. The detail in this work is very precise. There are more people and items in the scene with several features. For instance the pottery found in various places has fine points of detail painted on it. If you look

from faces to hands. In older paintings, people tend to have features that are too small in comparison to the rest of their body, like faces and hands for example. However, in this picture the features of the people seem to be more in proportion to other parts of the body. This can also indicate that an optical device was used. The artist of this painting, Benjamin West, experimented with camera obscures. It was said that when West became ill he was resting in a dark room. He then began to see a cow and pigs walk across the ceiling of the room. After he recovered, he investigated to see what had occurred. He found a hole in the shutters of the window. After experimenting with this find, he was able to make what is known now as a camera obscura. This was able to duplicate images. Artists later have also been known to use camera obscures to help with painting and drawing.

This knowledge coupled with my observations of the paintings has allowed me to chose which painting I believe to be made using an optical device. In conclusion, Benjamin West's painting was the one that fills this criteria. His painting seems to be the most detailed of the ones I have examined. It also appears to have the best proportions of human features. I also researched some of West's past in which he made a camera obscura. Based on these observations, I can say that he used an optical device when creating the picture.

CMA Activity

Artists have been creating paintings for many centuries. Over time there have been great improvements in the quality of the pictures. A few people have noticed that this major improvement happened over an unusually short time period. The reason could be that the artists themselves are extremely talented or that they were able to use tools such as an optical device to help them that earlier artists did not have. There is no proof to either of these reasons, but we can speculate by examining the paintings of several artists from different time periods. There are a few details that you notice if you look closely at the paintings. For example, examine the proportions of the body, facial structure, and details such as clothes or objects. In some paintings you can see how clear and realistic these details are. I will inspect three paintings by different artists and attempt to find which painting may have been painted with the help of an optical lens.

The first painting is titled The Crucifixion of Saint Andrew by Caravaggio and it hangs in gallery 217 at the Cleveland Museum of Art. This piece was painted around 1607, which is a time period that was after the creation of optical devices. After examining the painting I noticed several things. The feature that stood out to me the most was the emotion and detail of the faces in the portrait. You can see the wrinkles on the face of the man being crucified, the hair, and his eyes in great detail. Also, notice the other five men in the portrait also have distinct faces. They all look like real people you would see, unlike earlier paintings. The hands, arms, legs, and torso are proportionate to the body. You can also see great detail in the body from the muscles of his arms and chest to the skin of his wrists against his bonds. The clothes are simple, but have many folds and shadows on them. You can see the man at the bottom of the painting is wearing armor. The armor has some detail to it, but nothing extremely fancy.

The next painting is Portrait of a Woman by Gerard Terborch II. This painting was done in 1640, about thirty years later than the first painting discussed. At first glance, you notice the great detail of the woman's dress. The dress has many ruffles and beads done in great detail. This gives some reason that an optical device may have been used. However, I also noted that the woman's hands are extremely small for her body and face. You can also see that the arms are very long for her body. The face of the woman is a bit plain. Her face does not have any striking features and not many details. You can see the table and chair in the background are pretty simple. They are a bit fuzzy looking and are not very clear.

The final painting is Portrait of a Family Playing Music by Pieter de Hooch. The portrait was painted in about 1663. You can see that there is a lot in the background of the picture, but it is not as clearly detailed as some paintings. The furniture and walls are well done, but the lines look fuzzy and undefined. They aren't as clear as other paintings. I next noticed the people in the portrait have oddly shaped bodies. The hands are very small for the rest of their bodies and are not quite proportionate. The faces of the people look

In conclusion, I believe that the picture that was painted using an optical device was The Crucifixion of Saint Andrew by Caravaggio. This painting is full of minute details that give the painting a realistic effect. Unlike the other two paintings, the hands and arms are proportionate to their bodies. The faces of the people in the picture look human and have characters of their own. You can see the characteristics of their faces even from a distance. This is unlike the other paintings where the people look a bit too similar. These statements alone can not prove that this portrait was painted using an optical device. There is a possibility that the artists did use aid such as an optical device in painting this picture, but we can never really know for sure.

Name: _____ **Class:** _____ **Date:** _____ **ID: A**

Camera Obscura Quiz

Multiple Choice
Identify the letter of the choice that best completes the statement or answers the question.

____ 1. An incident ray strikes a plane mirror at 42degrees, at what angle is it refracted?
a. 42 degrees
b. 48 degrees
c. 90 degrees
d. it's not
e. 54 degrees

____ 2. A ray of light incident upon a plane mirror makes an angle of 28 degrees between the ray and the mirror. What is the angle between the incident ray and the reflected ray?
a. 28 degrees
b. 56 degrees
c. 62 degrees
d. 78 degrees
e. 124 degrees

____ 3. An example of a luminous object would be:
a. moon
b. disco ball
c. television
d. none of these
e. radio

____ 4. An example of an illuminated object is:
a. none of these
b. lightning
c. Sun
d. Earth
e. laser

____ 5. A flat smooth surface that reflects light rays by regular reflection not diffuse reflection.
a. plane mirror
b. concave mirror
c. convex mirror
d. diverging mirror
e. converging mirror

____ 6. A source of diverging light rays, may be luminous or illuminated.
a. virtual image
b. lens
c. object
d. real image
e. aberration

____ 7. Reproduction of object formed with mirrors or lenses.
a. aberration
b. image
c. object
d. focal length
e. focal point

____ 8. The point where parallel light rays converge or appear to diverge after reflecting from a mirror or refracting from a lens.
a. principal axis
b. focal length
c. focal point
d. radius of curvature
e. center of curvature

____ 9. An optical image formed when light rays converge and pass through the image.
a. erect image
b. aberrant image
c. virtual image
d. inverted image
e. real image

____ 10. The optical enlargement of an object.
a. magnification
b. aberration
c. chromatic effect
d. spherical anomaly
e. convergent image

____ 11. A transparent optical devise with a larger refractive index than air, used to converge or diverge light.
a. spherical aberration
b. mirror
c. chromatic aberration
d. optical density
e. lens

____ 12. A converging lens, thinner at it's out edge than at it's center.
a. convex lens
b. concave lens
c. plane lens
d. aberrant lens
e. none of the above

____ 13. White, glowing, or luminous with intense heat
a. fluorescent
b. incandescent
c. chemo-luminescent
d. LED

____ 14. producing light when electricity flows through a tube that is filled with a type of gas
a. fluorescent
b. incandescent
c. chemo-luminescent
d. LED

____ 15. Light produced by a chemical reaction
a. fluorescent
b. incandescent
c. chemo-luminescent
d. LED

____ 16. Two semiconductors close enough together for electrons to jump the gap between them and produce light.
a. fluorescent
b. incandescent
c. chemo-luminescent
d. LED

____ 17. A straight line representing the path of a narrow beam of light
a. image
b. luminous
c. ray
d. illuminated

____ 18. A body that emits light
a. image
b. luminous
c. ray
d. illuminated

____ 19. A body that reflects light
a. image
b. luminous
c. ray
d. illuminated

____ 20. A visual representation of something
a. image
b. luminous
c. ray
d. illuminated

____ 21. A source of spreading, or diverging light rays
a. virtual image
b. object
c. reflection
d. real image

____ 22. The bouncing back of a particle or wave that strikes the boundary between two media.
a. virtual image
b. object
c. reflection
d. real image

____ 23. Light does not converge to form this

a. virtual image
b. object
c. reflection
d. real image

____ 24. Light converges to form this

a. virtual image
b. object
c. reflection
d. real image

____ 25. A carefully ground or molded piece of transparent material which refracts light rays in such as way as to form an image

a. mirror
b. focal point
c. object
d. lens

____ 26. The spot where light rays passing through a converging lens converge.

a. 2F
b. focal point
c. principle axis
d. focal length

____ 27. The position that is twice the distance of the focal point

a. 2F
b. focal point
c. principle axis
d. focal length

____ 28. The horizontal axis of a lens

a. 2F
b. focal point
c. principle axis
d. focal length

____ 29. The distance from the vertical axis to the focal point

a. 2F
b. focal point
c. principle axis
d. focal length

____ 30. The change in direction of a wave (bending) as it crosses the boundary between two media in which the wave travels at different speeds

a. deflection
b. reflection
c. refraction
d. diffusion

____ 31. The reflected wave will reflect at the same angle as the incident wave strikes the surface.

a. law of reflection
b. inverse square law
c. magnification
d. thin lens equation

____ 32. The intensity of light on an object from a luminous source will decrease as the square of the distance between them increases.

a. law of reflection
b. inverse square law
c. magnification
d. thin lens equation

____ 33. The ratio of the height of the object to the height of the image

a. law of reflection
b. inverse square law
c. magnification
d. thin lens equation

____ 34. $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$

a. law of reflection
b. inverse square law
c. magnification
d. thin lens equation

Problem

A skin cell is placed on a microscope slide 14mm from the objective lens. The focal length of the objective lens is 10mm.

35. How far from the lens is the image formed?

36. The focal length of a convex lens is 14cm an object is placed 280mm in front of the lens. Draw a ray diagram to locate the image.

Camera Obscura Quiz
Answer Section

MULTIPLE CHOICE

1. ANS: D
2. ANS: E
3. ANS: C
4. ANS: D
5. ANS: A
6. ANS: C
7. ANS: B
8. ANS: C
9. ANS: E
10. ANS: A
11. ANS: E
12. ANS: A
13. ANS: B
14. ANS: A
15. ANS: C
16. ANS: D
17. ANS: C
18. ANS: B
19. ANS: D
20. ANS: A
21. ANS: B
22. ANS: C
23. ANS: A
24. ANS: D
25. ANS: D
26. ANS: B
27. ANS: A
28. ANS: C
29. ANS: D
30. ANS: C
31. ANS: A
32. ANS: B
33. ANS: C
34. ANS: D

PROBLEM

35. ANS:

35

di = 35 1/f=1/do+1/di

36. ANS:
inverted at 28cm other side of lens.

Camera Obscura Quiz [Answer Strip] **ID: A**

D 1.

E 2.

C 3.

D 4.

A 5.

C 6.

B 7.

C 8.

E 9.

A 10.

E 11.

A 12.

B 13.

A 14.

C 15.

D 16.

C 17.

B 18.

D 19.

A 20.

B 21.

C 22.

A 23.

D 24.

D 25.

B 26.

A 27.

C 28.

D 29.

C 30.

B 31.

B 32.

C 33.

D 34.

Class: _____ Date: 4/8/11 ID: A

100% AWESOME!

Multiple Choice

Identify the letter of the choice that best completes the statement or answers the question.

d 1. An incident ray strikes a plane mirror at 42degrees, at what angle is it refracted?
   a. 42 degrees
   b. 48 degrees
   c. 90 degrees
   d. it's not
   e. 54 degrees

e 2. A ray of light incident upon a plane mirror makes an angle of 28 degrees between the ray and the mirror. What is the angle between the incident ray and the reflected ray?
   a. 28 degrees
   b. 56 degrees
   c. 62 degrees
   d. 78 degrees
   e. 124 degrees

C 3. An example of a luminous object would be:
   a. moon
   b. disco ball
   c. television
   d. none of these
   e. radio

d 4. An example of an illuminated object is:
   a. none of these
   b. lightning
   c. Sun
   d. Earth
   e. laser

a 5. A flat smooth surface that reflects light rays by regular reflection not diffuse reflection.
   a. plane mirror
   b. concave mirror
   c. convex mirror
   d. diverging mirror
   e. converging mirror

C 6. A source of diverging light rays, may be luminous or illuminated.
   a. virtual image
   b. lens
   c. object
   d. real image
   e. aberration

b 7. Reproduction of object formed with mirrors or lenses.
   a. aberration
   b. image
   c. object
   d. focal length
   e. focal point

C 8. The point where parallel light rays converge or appear to diverge after reflecting from a mirror or refracting from a lens.
   a. principal axis
   b. focal length
   c. focal point
   d. radius of curvature
   e. center of curvature

e 9. An optical image formed when light rays converge and pass through the image.
   a. erect image
   b. aberrant image
   c. virtual image
   d. inverted image
   e. real image

a 10. The optical enlargement of an object.
   a. magnification
   b. aberration
   d. spherical anomaly
   e. convergent image

lass: 1 Date: 4/8/11 ID: A

100% great Job!

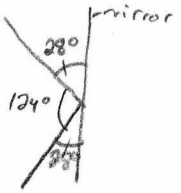
Multiple Choice

Identify the letter of the choice that best completes the statement or answers the question.

D. 1. An incident ray strikes a plane mirror at 42degrees, at what angle is it refracted?
   a. 42 degrees
   b. 48 degrees
   c. 90 degrees
   d. it's not
   e. 54 degrees

Nice ↑

C. 2. A ray of light incident upon a plane mirror makes an angle of 28 degrees between the ray and the mirror. What is the angle between the incident ray and the reflected ray?
   a. 28 degrees
   b. 56 degrees
   c. 62 degrees
   d. 78 degrees
   e. 124 degrees



C. 3. An example of a luminous object would be:
   a. moon
   b. disco ball
   c. television
   d. none of these
   e. radio

D. 4. An example of an illuminated object is:
   a. none of these
   b. lightning
   c. Sun
   d. Earth
   e. laser

A. 5. A flat smooth surface that reflects light rays by regular reflection not diffuse reflection.
   a. plane mirror
   b. concave mirror
   c. convex mirror
   d. diverging mirror
   e. converging mirror

C. 6. A source of diverging light rays, may be luminous or illuminated.
   a. virtual image
   b. lens
   c. object
   d. real image
   e. aberration

B. 7. Reproduction of object formed with mirrors or lenses.
   a. aberration
   b. image
   c. object
   d. focal length
   e. focal point

C. 8. The point where parallel light rays converge or appear to diverge after reflecting from a mirror or refracting from a lens.
   a. principal axis
   b. focal length
   c. focal point
   d. radius of curvature
   e. center of curvature

E. 9. An optical image formed when light rays converge and pass through the image.
   a. erect image
   b. aberrant image
   c. virtual image
   d. inverted image
   e. real image

A. 10. The optical enlargement of an object.
   a. magnification
   b. aberration
   d. spherical anomaly
   e. convergent image

Date: 4-8-11 ID: A

Camera Obscura Quiz -1 23/24 OUTSTANDING!

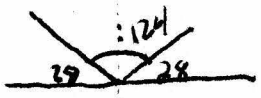
Multiple Choice

Identify the letter of the choice that best completes the statement or answers the question.

D. 1. An incident ray strikes a plane mirror at 42degrees, at what angle is it refracted?
   a. 42 degrees
   b. 48 degrees
   c. 90 degrees
   d. it's not
   e. 54 degrees

NICE↑

A. 2. A ray of light incident upon a plane mirror makes an angle of 28 degrees between the ray and the mirror. What is the angle between the incident ray and the reflected ray?
   a. 28 degrees
   b. 56 degrees
   c. 62 degrees
   d. 78 degrees
   e. 124 degrees



C. 3. An example of a luminous object would be:
   a. moon
   b. disco ball
   c. television
   d. none of these
   e. radio

D. 4. An example of an illuminated object is:
   a. none of these
   b. lightning
   c. Sun
   d. Earth
   e. laser

A. 5. A flat smooth surface that reflects light rays by regular reflection not diffuse reflection.
   a. plane mirror
   b. concave mirror
   c. convex mirror
   d. diverging mirror
   e. converging mirror

C. 6. A source of diverging light rays, may be luminous or illuminated.
   a. virtual image
   b. lens
   c. object
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B. 7. Reproduction of object formed with mirrors or lenses.
   a. aberration
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C. 8. The point where parallel light rays converge or appear to diverge after reflecting from a mirror or refracting from a lens.
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E. 9. An optical image formed when light rays converge and pass through the image.
   a. erect image
   b. aberrant image
   c. virtual image
   d. inverted image
   e. real image

A 10. The optical enlargement of an object.
   a. magnification
   b. aberration
   d. spherical anomaly
   e. convergent image

_____ Date: _____ ID: A

Camera Obscura Quiz -6 18/24

Multiple Choice
Identify the letter of the choice that best completes the statement or answers the question.

X 1. An incident ray strikes a plane mirror at 42degrees, at what angle is it refracted?
a. 42 degrees
b. 48 degrees
c. 90 degrees
d. it's not
e. 54 degrees

E 2. A ray of light incident upon a plane mirror makes an angle of 28 degrees between the ray and the mirror. What is the angle between the incident ray and the reflected ray?
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d. inverted image
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a 10. The optical enlargement of an object.
a. magnification
b. aberration
d. spherical anomaly
e. convergent image

_____ Date: 4/8/11 ID: A

Camera Obscura Quiz -6 18/24

Multiple Choice
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   a. 42 degrees
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   c. 90 degrees
   d. it's not
   e. 54 degrees

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   c. virtual image
   d. inverted image
   e. real image

a 10. The optical enlargement of an object.
   a. magnification
   b. aberration
   d. spherical anomaly
   e. convergent image

1° Date: 04-09-11 ID: A

Camera Obscura Quiz -6 18/24

Multiple Choice
Identify the letter of the choice that best completes the statement or answers the question.

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c. virtual image
d. inverted image
e. real image

a 10. The optical enlargement of an object.
a. magnification
b. aberration
d. spherical anomaly
e. convergent image

10 Date: 4-08-11 ID: A

Camera Obscura Quiz

-7 17/24

∠incident = ∠reflected

Multiple Choice
Identify the letter of the choice that best completes the statement or answers the question.

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   a. 42 degrees
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   c. 90 degrees
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   e. 54 degrees

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   c. virtual image
   d. inverted image
   e. real image

A 10. The optical enlargement of an object.
   a. magnification
   b. aberration
   d. spherical anomaly
   e. convergent image

Blk 1 Date: 4-8-11 ID: A

Camera Obscura Quiz

-7 17/24

Multiple Choice
Identify the letter of the choice that best completes the statement or answers the question.

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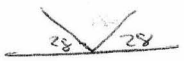

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e. real image

A 10. The optical enlargement of an object.
a. magnification
b. aberration
d. spherical anomaly
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Block 1 Date: 04/08/11 ID: A

Camera Obscura Quiz

-7 17/24

Multiple Choice
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Name: _____ Date: 4-8-2011 ID: A

Camera Obscura Quiz

-8 16/24

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a. magnification
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[redacted] Date: 4-7-11 ID: A

Camera Obscura Quiz

-8 16/24

Multiple Choice
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Date: 4/6/11 ID: A

Camera Obscura Quiz

-9 15 24

Multiple Choice
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Name: _____ Date: _____ ID: A

Camera Obscura Quiz

-9 15/24

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P _____ Date: 4-6-11 ID: A

Camera Obscura Quiz -10 14/24

Multiple Choice
Identify the letter of the choice that best completes the statement or answers the question.

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Name: _____ Period: 10 Date: 4/8/11 ID: A

Camera Obscura Quiz

-11 13/24

Multiple Choice
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Name: _____ Date: _____ ID: A

Camera Obscura Quiz

-11 13/24

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   c. Sun
   d. Earth
   e. laser

F 5. A flat smooth surface that reflects light rays by regular reflection not diffuse reflection.
   a. plane mirror
   b. concave mirror
   c. convex mirror
   d. diverging mirror
   e. converging mirror

C 6. A source of diverging light rays, may be luminous or illuminated.
   a. virtual image
   b. lens
   c. object
   d. real image
   e. aberration

B 7. Reproduction of object formed with mirrors or lenses.
   a. aberration
   b. image
   c. object
   d. focal length
   e. focal point

A 8. The point where parallel light rays converge or appear to diverge after reflecting from a mirror or refracting from a lens.
   a. principal axis
   b. focal length
   c. focal point
   d. radius of curvature
   e. center of curvature

C 9. An optical image formed when light rays converge and pass through the image.
   a. erect image
   b. aberrant image
   c. virtual image
   d. inverted image
   e. real image

A 10. The optical enlargement of an object.
   a. magnification
   b. aberration
   d. spherical anomaly
   e. convergent image

Block 10 Date: 4/15/11 ID: A

Camera Obscura Quiz

-12 12/24

Multiple Choice
Identify the letter of the choice that best completes the statement or answers the question.

a. 1. An incident ray strikes a plane mirror at 42degrees, at what angle is it refracted?
a. 42 degrees
b. 48 degrees
c. 90 degrees
d. it's not
e. 54 degrees

e. 2. A ray of light incident upon a plane mirror makes an angle of 28 degrees between the ray and the mirror. What is the angle between the incident ray and the reflected ray?
a. 28 degrees
b. 56 degrees
c. 62 degrees
d. 78 degrees
e. 124 degrees

a 3. An example of a luminous object would be:
a. moon
b. disco ball
c. television
d. none of these
e. radio

a. 4. An example of an illuminated object is:
a. none of these
b. lightning
c. Sun
d. Earth
e. laser

a. 5. A flat smooth surface that reflects light rays by regular reflection not diffuse reflection.
a. plane mirror
b. concave mirror
c. convex mirror
d. diverging mirror
e. converging mirror

b. 6. A source of diverging light rays, may be luminous or illuminated.
a. virtual image
b. lens
c. object
d. real image
e. aberration

b. 7. Reproduction of object formed with mirrors or lenses.
a. aberration
b. image
c. object
d. focal length
e. focal point

c. 8. The point where parallel light rays converge or appear to diverge after reflecting from a mirror or refracting from a lens.
a. principal axis
b. focal length
c. focal point
d. radius of curvature
e. center of curvature

b. 9. An optical image formed when light rays converge and pass through the image.
a. erect image
b. aberrant image
c. virtual image
d. inverted image
e. real image

b. 10. The optical enlargement of an object.
a. magnification
b. aberration
d. spherical anomaly
e. convergent image

Name: _____ Date: 4/8/11 ID: A

Camera Obscura Quiz

-12 12/24

Multiple Choice
Identify the letter of the choice that best completes the statement or answers the question.

A. 1. An incident ray strikes a plane mirror at 42degrees, at what angle is it refracted?
   a. 42 degrees
   b. 48 degrees
   c. 90 degrees
   d. it's not
   e. 54 degrees

C. 2. A ray of light incident upon a plane mirror makes an angle of 28 degrees between the ray and the mirror. What is the angle between the incident ray and the reflected ray?
   a. 28 degrees
   b. 56 degrees
   c. 62 degrees
   d. 78 degrees
   e. 124 degrees

A. 3. An example of a luminous object would be:
   a. moon
   b. disco ball
   c. television
   d. none of these
   e. radio

C. 4. An example of an illuminated object is:
   a. none of these
   b. lightning
   c. Sun
   d. Earth
   e. laser

E. 5. A flat smooth surface that reflects light rays by regular reflection not diffuse reflection.
   a. plane mirror
   b. concave mirror
   c. convex mirror
   d. diverging mirror
   e. converging mirror

A. 6. A source of diverging light rays, may be luminous or illuminated.
   a. virtual image
   b. lens
   c. object
   d. real image
   e. aberration

D. 7. Reproduction of object formed with mirrors or lenses.
   a. aberration
   b. image
   c. object
   d. focal length
   e. focal point

C. 8. The point where parallel light rays converge or appear to diverge after reflecting from a mirror or refracting from a lens.
   a. principal axis
   b. focal length
   c. focal point
   d. radius of curvature
   e. center of curvature

E. 9. An optical image formed when light rays converge and pass through the image.
   a. erect image
   b. aberrant image
   c. virtual image
   d. inverted image
   e. real image

A. 10. The optical enlargement of an object.
   a. magnification
   b. aberration
   d. spherical anomaly
   e. convergent image

Student survey

The camera obscura lesson helped you understand reflection of light.

1 strongly disagree	2 disagree	3 neutral	4 agree	5 strongly agree

The camera obscura lesson helped you understand image formation with a convex lens.

1 strongly disagree	2 disagree	3 neutral	4 agree	5 strongly agree

The camera obscura lesson was enjoyable.

1 strongly disagree	2 disagree	3 neutral	4 agree	5 strongly agree

The directions were easy to understand when constructing the camera obscura.

1 strongly disagree	2 disagree	3 neutral	4 agree	5 strongly agree

This lesson taught me connections between art and science.

1 strongly disagree	2 disagree	3 neutral	4 agree	5 strongly agree

I learned something new during the course of this lesson.

1 strongly disagree	2 disagree	3 neutral	4 agree	5 strongly agree

I would recommend this lesson be used again in future classes.

1 strongly disagree	2 disagree	3 neutral	4 agree	5 strongly agree

I enjoyed this lesson.

1 strongly disagree	2 disagree	3 neutral	4 agree	5 strongly agree

I was excited to show others my camera obscura.

1 strongly disagree	2 disagree	3 neutral	4 agree	5 strongly agree

I understand why an image formed in a camera obscura is inverted.

1 strongly disagree	2 disagree	3 neutral	4 agree	5 strongly agree

What was your favorite part of the lesson and why? (ppt slides, hands on learning, camera obscura, room size camera obscura, other)

What could be added to this project to make it more fulfilling?

What could we have done differently?

Any additional comments or suggestions?

Student survey

The camera obscura lesson helped you understand reflection of light.

1 strongly disagree	2 disagree	3 neutral	4 agree	5 strongly agree

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I understand why an image formed in a camera obscura is inverted.

1 strongly disagree	2 disagree	3 neutral	4 agree	5 strongly agree

What was your favorite part of the lesson and why? (ppt slides, hands on learning, camera obscura, room size camera obscura, other)

Learning why images are upside down.

What could be added to this project to make it more fulfilling?

Cooler obscuras

What could we have done differently?

Nothing

Any additional comments or suggestions?

It was AWESOME!

Student survey

The camera obscura lesson helped you understand reflection of light.

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I would recommend this lesson be used again in future classes.

1 strongly disagree	2 disagree	3 neutral	4 agree	5 strongly agree

I enjoyed this lesson.

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I understand why an image formed in a camera obscura is inverted.

1 strongly disagree	2 disagree	3 neutral	4 agree	5 strongly agree

What was your favorite part of the lesson and why? (ppt slides, hands on learning, camera obscura, room size camera obscura, other)

The best part of the lesson for me was the roomsize camera obscura. Although it was not that great because their was not a lot of sunlight it was awesome to see and create.

What could be added to this project to make it more fulfilling?

Maybe something like making something we can keep like make our own camara.

What could we have done differently?

Everything was good.

Any additional comments or suggestions?

Student survey

The camera obscura lesson helped you understand reflection of light.

1 strongly disagree	2 disagree	3 neutral	4 agree	5 strongly agree

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The camera obscura lesson was enjoyable.

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The directions were easy to understand when constructing the camera obscura.

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This lesson taught me connections between art and science.

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I learned something new during the course of this lesson.

1 strongly disagree	2 disagree	3 neutral	4 agree	5 strongly agree

I would recommend this lesson be used again in future classes.

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I enjoyed this lesson.

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I was excited to show others my camera obscura.

1 strongly disagree	2 disagree	3 neutral	4 agree	5 strongly agree

I understand why an image formed in a camera obscura is inverted.

1 strongly disagree	2 disagree	3 neutral	4 agree	5 strongly agree

What was your favorite part of the lesson and why? (ppt slides, hands on learning, camera obscura, room size camera obscura, other) Hands on learning was my favorite part because that is the way I learn best.

What could be added to this project to make it more fulfilling? A little more materials could be available.

What could we have done differently? Nothing.

Any additional comments or suggestions? No.

Student survey

The camera obscura lesson helped you understand reflection of light.

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I understand why an image formed in a camera obscura is inverted.

1 strongly disagree	2 disagree	3 neutral	4 agree	5 strongly agree

What was your favorite part of the lesson and why? (ppt slides, hands on learning, camera obscura, room size camera obscura, other) The actual picture that came out

What could be added to this project to make it more fulfilling?

better materials

What could we have done differently?

better images

Any additional comments or suggestions?

nope

Student survey

The camera obscura lesson helped you understand reflection of light.

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I would recommend this lesson be used again in future classes.

1 strongly disagree	2 disagree	3 neutral	4 agree	5 strongly agree

I enjoyed this lesson.

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I was excited to show others my camera obscura.

1 strongly disagree	2 disagree	3 neutral	4 agree	5 strongly agree

I understand why an image formed in a camera obscura is inverted.

1 strongly disagree	2 disagree	3 neutral	4 agree	5 strongly agree

What was your favorite part of the lesson and why? (ppt slides, hands on learning, camera obscura, room size camera obscura, other)

I liked the fact that there was a lot of hands on learning this lesson. It made science more interesting with the art.

What could be added to this project to make it more fulfilling?

A field trip would be nice.

What could we have done differently?

Made the camera obscura with some sort of lense

Any additional comments or suggestions?

Student survey

The camera obscura lesson helped you understand reflection of light.

1 strongly disagree	2 disagree	3 neutral	4 agree	5 strongly agree

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I would recommend this lesson be used again in future classes.

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I was excited to show others my camera obscura.

1 strongly disagree	2 disagree	3 neutral	4 agree	5 strongly agree

I understand why an image formed in a camera obscura is inverted.

1 strongly disagree	2 disagree	3 neutral	4 agree	5 strongly agree

What was your favorite part of the lesson and why? (ppt slides, hands on learning, camera obscura, room size camera obscura, other) I enjoyed the room size camera obscura because it allowed us to see how the camera worked on a larger scale and how it projected the outside surroundings.

What could be added to this project to make it more fulfilling?
I think there could be more of a variety for the objects we seen through the camera obscura.

What could we have done differently?
To me everything was done well so there is no need to do anything differently.

Any additional comments or suggestions?
On the day that the room size camera obscura is used it should be done on a brighter day so the image can be seen even more clearly.

Student survey

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The directions were easy to understand when constructing the camera obscura.

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I would recommend this lesson be used again in future classes.

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I understand why an image formed in a camera obscura is inverted.

1 strongly disagree	2 disagree	3 neutral	4 agree	5 strongly agree

What was your favorite part of the lesson and why? (ppt slides, hands on learning, camera obscura, room size camera obscura, other) - My favorite part of the lesson was the CAMERA OBSCURA because it was hands on and I understood the lesson better after making the camera obscura.

What could be added to this project to make it more fulfilling?

Maybe more time so everything is not rushed and we are able to better understand the lesson.

What could we have done differently?

I think that everything was done fine. just more time would have been nice

Any additional comments or suggestions?

I think that this is was a very good lesson / project. It helped me better understand the lessons.

Student survey

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This lesson taught me connections between art and science.

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I learned something new during the course of this lesson.

1 strongly disagree	2 disagree	3 neutral	4 agree	5 strongly agree

I would recommend this lesson be used again in future classes.

1 strongly disagree	2 disagree	3 neutral	4 agree	5 strongly agree

I enjoyed this lesson.

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I was excited to show others my camera obscura.

1 strongly disagree	2 disagree	3 neutral	4 agree	5 strongly agree

I understand why an image formed in a camera obscura is inverted.

1 strongly disagree	2 disagree	3 neutral	4 agree	5 strongly agree

What was your favorite part of the lesson and why? (ppt slides, hands on learning, camera obscura, room size camera obscura, other) My favorite part of the lesson was the powerpoint slide.

What could be added to this project to make it more fulfilling?
making a large scale obscura in different locations of the school.

What could we have done differently?

Any additional comments or suggestions?

Student survey

The camera obscura lesson helped you understand reflection of light.

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I would recommend this lesson be used again in future classes.

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I was excited to show others my camera obscura.

1 strongly disagree	2 disagree	3 neutral	4 agree	5 strongly agree

I understand why an image formed in a camera obscura is inverted.

1 strongly disagree	2 disagree	3 neutral	4 agree	5 strongly agree

What was your favorite part of the lesson and why? (ppt slides, hands on learning, camera obscura, room size camera obscura, other)

My favorite part of the lesson was the construction of the camera obscura. It was very interesting to build and add on to the design. I ejoyed using it and it was very interesting.

What could be added to this project to make it more fulfilling?

I think that you could bring in a professional camera obscura to compare ours to. It would be interesting to use + see how the images compare.

What could we have done differently?

We could have used several more objects to look at and compare. It would have been nice to see different images inverted other than just one.

Any additional comments or suggestions?

I highly recommend this project to other classes learning about light + images. It was fascinating to build our own camera obscuras and actually use them.

CMA Complementary Learning Workshop

INSTRUCTOR REPORT

Instructor Name: __Seamus Joyce_____

School Name: _____Architecture and Design at John Hay_____

Date(s) Unit Delivered: ___April 2011_____ Grade Level: ___12__

Course/Subject Name: __Physics_____ # Students Enrolled: ____20_

Unit Title: __Camera Obscura , light, and the convex lens_____

1. Please describe the Unit you developed and its concept/focus.

This is a Science and Art integrated lesson using hand held and a classroom size camera obscura to introduce the behavior of light as it travels; it's interaction with a flat mirror and a convex lens as well as the inverse square law, law of reflection, thin lens equation and magnification equation.

2. Please identify up to five learning objectives for the Unit.

	Extent to which you believe this learning objective was achieved….	Completely	High	Moderate	Low	Not at all
a.	_how light behaves as it travels_____	☐	☒	☐	☐	☐
b.	__law of reflection___	☐	☒	☐	☐	☐
c.	___inverse square law_____	☐	☒	☐	☐	☐
d.	___thin lens equation_____	☐	☒	☐	☐	☐
e.	____magnification equation_____	☐	☒	☐	☐	☐

3. Please rate the following aspects of the Unit.

	In regard to the overall presentation, please address the following items…	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
a.	The Unit was deliverable in the way I had designed it	☒	☐	☐	☐	☐
b.	I feel I did a good job delivering the content of the Unit	☒	☐	☐	☐	☐
c.	The students were engaged during the Unit	☒	☐	☐	☐	☐

4. One of the things that worked very well about the Unit was…

Building the hand held camera obscuras. When the students were able to form an image with the obscura they were amazed that it was inverted and complete engaged in wanting to figure out why the image was inverted. They were also very impressed when we turned the classroom into a giant camera obscura.

5. Ways in which you think art improved the lesson include…

Seeing photographs from the CMA collection of camera obscura images and discussing the possibility of Artists using the camera obscura while painting engaged the students interest. Then seeing the paintings in person at the CMA enhanced the real life application of science beyond the idea that science only happens in a boring laboratory.

6. Any other comments you have about your experience delivering the Unit…

I will definitely teach this lesson again, the only thing that would enhance the lesson is better weather. It was really sunny the week before I taught the lesson, but the day we turned the classroom into a camera obscura the weather turned on us and the sky was very overcast. Consequently the image formed was fairly dim.